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No. 25

NATURE AND DEVELOPMENT OF LEARNING CAPACITY

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Nature and Development of Learning Capacity

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CONTENTS

PREFACE

The science of education rests primarily upon the science of psychology, particularly that branch of psychology which deals with the nature and development of children.

The following experiments are reported in the hope that they may make some slight contribution to the psychology of child development. Working out this problem in extensive and complete fashion will require the patient work of many investigators for many years. The extensive work must be financed by the state and national governments, by wealthy private individuals, or by endowments.

The experiments reported here were made possible by small grants from the University of Missouri. I wish to acknowledge the co-operation of Deans J. H. Coursault and M. G. Neale, President Stratton D. Brooks and former President J. C. Jones, of the University of Missouri. In most of the later experiments I have had the valuable assistance of Mr. E. L. Schott.

W. H. P.

NATURE AND DEVELOPMENT
OF
LEARNING CAPACITY

CHAPTER I

AIMS AND METHODS

The Problem.—The purpose of the studies reported in this book is to discover the nature and course of mental development with particular reference to the development of learning capacity. Some of the questions which we try to answer are: What is the course of development of the ability to learn? How does the rate of development in one year compare with the rates in other years? Is the development of one aspect of learning different from the development of other aspects? In other words, to what extent is learning a general function and to what extent is it a specific function? What are the sex differences in learning capacity? Are there any sex differences in variability? How great are mental differences in children of the same age? How much overlapping is there in the frequency surfaces of adjacent years and of adjacent grades? What is the nature of the difference in learning capacity of good and poor learners? What differences are there between city and country children with reference to mental development? What are the racial differences in capacity to learn? What bearing do the answers to these various

questions have on problems of teaching and administration in the public schools? Finally, what light do our results throw upon the question of the nature of learning capacity?

The Experiments.—The experimental studies considered here have covered a period of ten years and include studies of negroes, Indians, and Chinese, as well as more extensive studies of white American children in both city and country. The most important experiments, however, are those on the nature and development of learning capacity which have been carried out in the last two years. The total number of children studied is about fifteen thousand. A detailed description will be given here of only the more recent work, since the results of the earlier studies have already been published.

The plan of procedure in these experiments has been to study the development of school children with reference to several different aspects of learning capacity. I have tried especially to measure, in addition to the ordinary types of ideational learning, those types of learning properly called habit formation, or sensori-motor learning. This type of learning has been somewhat neglected in recent mental measurement.

The experiments have all been planned on the assumption that learning is connecting. In habit formation learning is connecting stimulus with response. In ideational learning, the connection established is between ideas, or, more properly speaking, between the cortical activities underlying the ideas. The various kinds of learning, therefore, involve different types of stimuli and different types of response. I shall give here only a general description of the different experiments, for they are described in detail as they are severally discussed in the following pages.

The card-sorting experiment consists merely in sorting cards according to number. The stimulus is the number. The response is putting the card containing the number into a particular place which is assigned the same number.

This is a very simple experiment of a very simple type of learning and can be given to children as soon as they know the Arabic numbers.

The marble-sorting experiment consists in sorting colors instead of numbers and is more complicated than card-sorting in that there are two sets of associations formed. In the first place, the colors of balls are associated with the forms of well-known animals. In the second place the animals are associated with certain locations on the box into which the balls are placed. This test can be given to children of any age inasmuch as it is not necessary to know the names of the colors. The experiment has the defect that it can not be given to color-blind children.

The manthanometer experiment is a sorting experiment also, but wholly different from the other two sorting experiments in that it involves a high degree of concentration and the ability to keep several processes in mind throughout the experiment. The subject produces his own stimulus by pressing an electric button. The stimulus is a colored disc which may be large or small and he must react both to its color and its size. The reaction consists of getting and placing a ball with the right hand and also with the left at the same time, while the feet manipulate pedals which direct the course of some of the balls.

The substitution experiment consists in associating letters with digits. The stimulus is the digit; the response is writing the proper letter. This experiment can be given only to children who know the digits and can make the letters

of the alphabet. It can not be used below the third grade and not with much success below the fourth grade.

The mirror experiment is a measure of trial-and-error learning. It consists in drawing when the stimulus is a reflection from a mirror which is vertical in front of the subject's hand. This experiment involves the breaking up of habits already formed. It is rather difficult for everybody and particularly for young children.

The ideational experiments are devised to measure that type of learning that is most common in school in all but the lowest grades. It consists in getting the meaning from printed stories.

The mental tests consist of two types of material: learning tests and tests of the organization of previous experience. They are therefore a more general measure of intelligence than either of the specific learning experiments and are included in this study chiefly for comparison with the learning experiments.

THE PSYCHO-EDUCATIONAL CLINIC

If procedure in American public schools is ever to be established on a scientific basis we must have a psycho-educational clinic as a part of every school system. The conductor of this clinic must be trained in psychology and psychological methods. He must be trained in methods of experimentation with special reference to school children.

Every child should proceed through the course of study at a pace commensurate with his ability and development. The bright should go fast, the dull much more slowly. Different types of pupils should have different courses of study. In settling questions concerning ability the teacher should have the assistance of an expert.

The psycho-educational expert should have a well equipped laboratory and should be provided with every

aid which science can give. It is the author's hope that this study will furnish methods and norms which will be of service in such a clinic.

When the proposal is made to school boards to establish such a clinic, they will doubtless object on the ground of the added expense involved. But it is certain that what we would save by doing the proper thing for every child would pay a hundred times over for the cost of running such a clinic as is here proposed. It is not economical to run a school on the shotgun method.

Under the present condition of things we do not know *why* we teach what we do. We do not know *how* to teach it. We do not know *what* we are teaching it to. The psycho-educational clinic would help us to know more about the *kinds* of being we are working with. The general field of Educational Psychology is to help solve the other problems mentioned.

CHAPTER II

THE CARD-SORTING EXPERIMENTS

Nature and Aim of the Experiment.—The purpose of this experiment is to determine the development in children from year to year of that type of learning required in sorting cards.

The learning involved here is merely the association of a number with a certain location on the card-sorting box. The quick learners soon know where each number belongs. Their speed of sorting therefore increases fast. The slow learners must continue to hunt for the numbers. Their sorting time therefore improves slowly.

Apparatus and Method.—The apparatus consists of card-sorting trays, seventy-five cards for each tray, and a Whipple clock. The tray is illustrated in figure 1. There are fifteen compartments, five in a row. The compartments are numbered and the cards are numbered to correspond, five cards of each number.

The procedure of the experiment as here reported was as follows: The card-sorting boxes were arranged on tables of suitable height. The pupils were seated at the tables. The cards were thoroughly shuffled. The experiment was carefully explained to the pupils, and the method of reading the clock was explained. They were told that the object of the experiment was to see how quickly they could sort the cards into the compartments of the tray, putting each card into the place having the same number as the card.

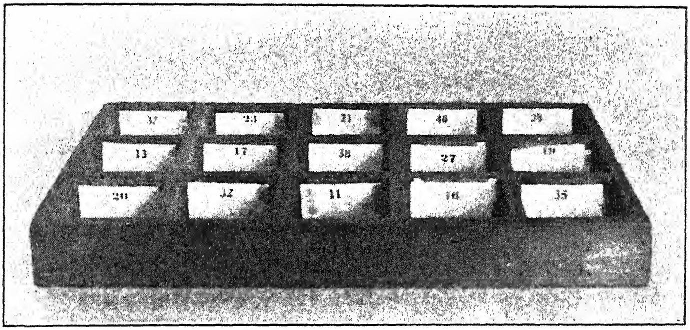

FIG. 1.—Card-sorting tray.

Each pupil was provided with a small slip of paper on which he recorded his name, age, grade, and sex. He was told to look at the clock the instant he finished sorting, note the time in minutes and seconds and record this time on his slip of paper. After all pupils finished, each pupil took up his cards, picking them up promiscuously so as to shuffle them as much as possible. The cards were then shuffled three times in the ordinary way of shuffling cards. If a pupil could not do it, the experimenter or a helper did it. Close watch was kept on all the work by the experimenter and helpers. Three sortings in all were made.

TABLE I

CARD-SORTING—THREE SORTINGS—AGE AND SEX AVERAGES

Age	Number of cases		Learning efficiency		Scores smoothed	
	Girls	Boys	Girls	Boys	Girls	Boys
8	66	47	104.4	92.2	100.0	90.0
9	139	120	123.4	108.3	123.4	108.3
10	162	130	148.7	124.3	145.0	124.3
11	182	142	158.2	136.0	158.0	136.0
12	191	162	164.4	148.4	169.0	148.4
13	175	172	178.0	165.6	178.0	162.0
14	188	184	188.8	170.2	187.0	173.0
15	178	143	192.2	177.7	194.0	181.0
16	148	121	196.0	191.9	197.5	190.0
17	127	72	200.8	196.3	202.0	196.0
18	41	33	204.0	185.3	204.0	200.0

The Results.—The first column gives the ages; the second and third give the number of cases; the fourth and fifth give the efficiencies for the different ages; the sixth and seventh give the efficiency scores somewhat smoothed.

The efficiency norms shown in table I are the result of experiments with 1597 girls and 1326 boys in four small Missouri cities. The actual averages are shown in columns four and five. The scores shown in columns six and seven are the result of a slight smoothing of the growth curves, and are perhaps nearer the truth than the actual averages. The smoothed records should be taken as norms. In determining learning efficiency each individual's combined score for the three sortings was taken, in seconds. The reciprocal of the number of seconds was taken as the measure of efficiency. The norms of table I were computed from the individual reciprocals. A word of explanation of this method of determining efficiency is necessary. In this experiment the amount of work done is constant—sorting seventy-five cards. The person who sorts them in the shortest time is the fastest learner; the one requiring the longest time is the slowest learner. If we express the sorting time in seconds, and then take the reciprocals of these numbers as representing efficiency, the one with fastest time is shown to have the highest efficiency score and the one with the slowest time, the lowest score. The same thing could be arrived at by computing the number of cards sorted per minute; but this is laborious, while the reciprocals can be read from a book of tables. In our practice we take the reciprocal with the decimal point and ciphers omitted.

In table II, the sex differences are expressed in months. From age eleven to eighteen the average difference in the learning capacity of boys and girls, as measured by this test,

TABLE II

CARD SORTING—SEX DIFFERENCES EXPRESSED IN MONTHS

Boys, Age		Girls, Yrs.-Mos.		Difference in Months
9	=	8	4.3	7.7
10	=	9	.5	11.5
11	=	9	8.0	16.0
12	=	10	3.4	20.6
13	=	11	4.8	19.2
14	=	12	5.3	18.7
15	=	13	4.5	19.5
16	=	14	6.9	17.1
17	=	16	6.0	18.0
18	=	16	9.2	14.8

is about eighteen months. During adolescence girls, on the average, have the learning capacity of boys eighteen months older. In the earlier years, the difference is not so great.

A further comparison of boys and girls is made in table III which shows the percentage which the boys' scores are of the corresponding scores of the girls. For ages

TABLE III

CARD SORTING—GIVING THE PERCENTAGE WHICH THE BOYS' SCORES ARE OF THE GIRLS' SCORES OF THE CORRESPONDING AGES

Age..............	8	9	10	11	12	13	14	15	16	17	18
	88	88	84	86	90	93	90	92	98	98	91

eight to twelve the efficiency of boys is, on the average, 88 per cent of that of girls, while for ages thirteen to eighteen, the boys come closer and closer to the girls, making, on the average, a score which is 94 per cent of that of girls. The percentages are computed from the actual averages.

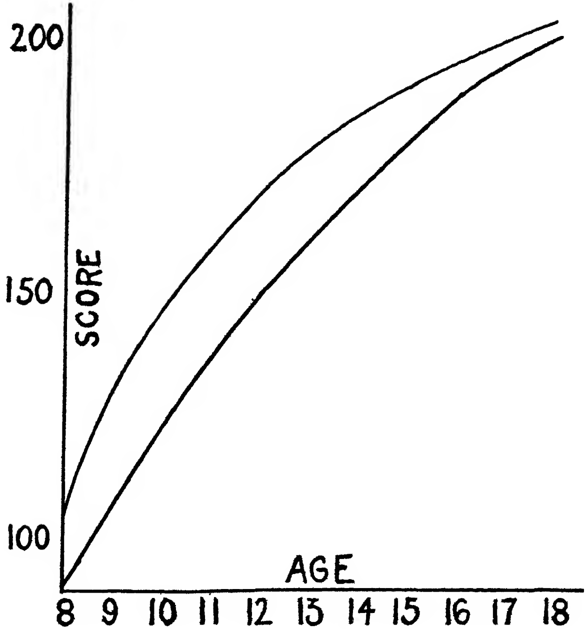

FIG. 2.—Growth curves for card-sorting. Upper curve is for girls, lower curve is for boys.

The growth in learning capacity in card sorting is shown graphically in figure 2. These graphs are constructed from the smoothed scores as shown in table I.

In table IV is shown the actual growth from year to year and the per cent of growth. This table is constructed from

TABLE IV

CARD SORTING—YEARLY GROWTH

Age	Boys		Girls	
	Actual growth	Per cent	Actual growth	Per cent
8 to 9	18.3	20.0	23.4	23.4
9 to 10	16.0	14.8	21.6	17.5
10 to 11	11.7	9.4	13.0	8.9
11 to 12	12.4	9.1	11.0	6.9
12 to 13	13.6	9.1	9.0	5.3
13 to 14	13.0	6.6	9.0	5.1
14 to 15	8.0	4.6	7.0	3.7
15 to 16	9.0	4.9	3.5	1.8
16 to 17	6.0	3.2	4.5	2.3
17 to 18	4.0	2.0	2.0	0.9

the smoothed scores of table I as follows: The efficiency score for girls at age eight is 100; for age nine it is 123.4. The actual growth is represented by the number 23.4, which is 23.4 per cent of the eight year score. The boys' score for age eight is 90; for age nine, 108.3, a difference of 18.3 which is 20 per cent of 90.

The per cents of growth for the various years are shown graphically in figure 3. The comparison is made by means

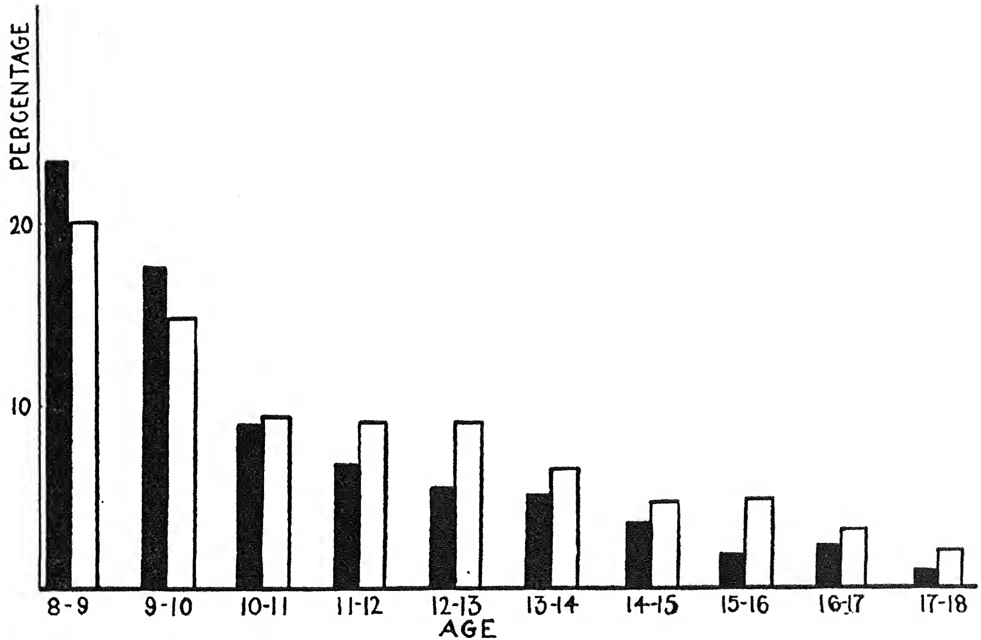

FIG. 3.—The vertical columns represent the yearly per cent of growth in card sorting. Black columns are for girls, light columns are for boys.

of parallel columns. The height of each column represents per cent of growth. It will be seen that the annual per cent of improvement in learning capacity is greater for girls up to age ten, and afterward the per cent of growth is greater for boys.

Table V gives the scores for the three sortings. The facts of table V are shown graphically in figure 4.

TABLE V

CARD SORTING—EFFICIENCY SCORES BY TRIALS

Age	1		2		3	
	Girls	Boys	Girls	Boys	Girls	Boys
8	236	206	302	265	360	314
9	283	242	352	312	415	375
10	333	292	422	365	490	426
11	370	319	459	395	549	472
12	382	352	474	429	555	495
13	435	400	518	485	613	559
14	472	413	559	500	625	581
15	474	426	549	513	641	599
16	493	472	578	568	654	658
17	515	480	599	575	680	685
18	515	478	606	552	680	625

The per cents of improvement from first to third are shown in table VI. The per cent of improvement is much the same for boys and girls, the average being 43 per cent for boys and 40 per cent for girls. Girls being the quicker learners, learn more, relatively, on the first sorting. Boys, being the slower learners, learn relatively more on the third sorting.

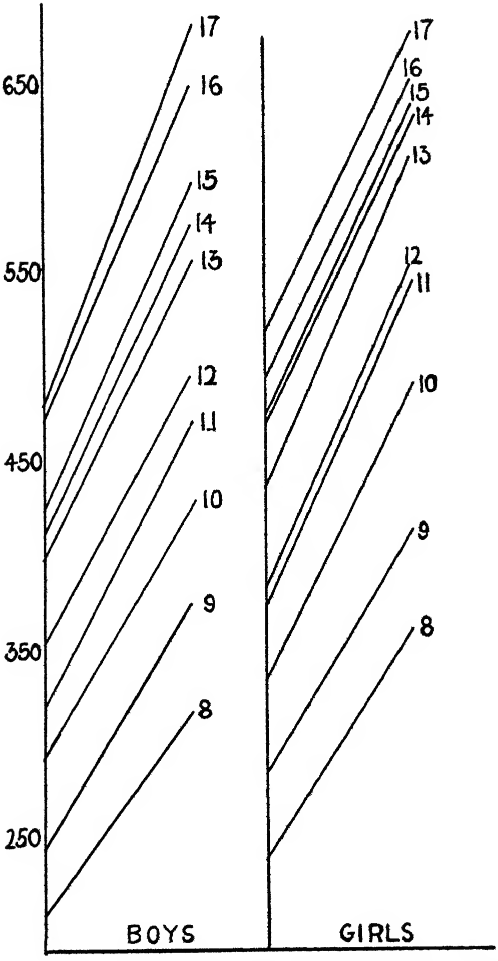

FIG. 4.—The graphs represent the improvement from the first to the third sorting of cards. The efficiency scores are represented on the vertical axis. The left end of the oblique graphs represent efficiency at first sorting, and the right end represents efficiency at the third sorting. The numbers to the right represent the ages.

TABLE VI

CARD SORTING—SHOWING THE PER CENT OF IMPROVEMENT FROM THE FIRST SORTING TO THE THIRD

Age	8	9	10	11	12	13	14	15	16	17	18	Ave.
Girls...	52	46	47	48	45	41	32	35	33	32	32	40
Boys...	52	55	46	48	41	40	41	41	39	42	31	43

As seen in table VI and figure 4, as pupils become older there is a smaller improvement from first to third sorting. The explanation is the same as for the sex difference in improvement from first to third sorting. The better learner learns quickly, the poor learner learns slowly. The good learner makes a high initial score; the poor learner makes a low initial score.

Table VII is given to show sex variability. It will be seen that the actual variability is almost exactly the same for boys as for girls, but the percentage is slightly greater for boys. In general, there is a decrease in variability with age. The average of girls from eight to twelve is 24.7, for boys 26.3. The corresponding figures for thirteen to eighteen are for girls 16.7, for boys 20.8.

Discussion of Results.—The tables and graphs show a steady increase in learning capacity for both boys and girls for this type of motor learning from age eight to age eighteen. The efficiency of girls is greater at every age, due to the early rapid development of girls. Up to age ten girls have a higher percentage of annual growth in learning capacity—as measured by this experiment—than boys. This early faster growth puts the girl about eighteen months ahead in

TABLE VII

CARD SORTING—VARIABILITY WITH REFERENCE TO AGE AND SEX

Age	Score		Standard deviation		Coefficient of variability	
	Girls	Boys	Girls	Boys	Girls	Boys
8	104.4	92.2	28.7	32.4	27.5	35.1
9	123.4	108.3	33.8	32.4	27.4	30.0
10	148.7	124.3	33.5	28.1	22.5	22.6
11	158.2	136.0	36.4	28.3	23.0	20.8
12	164.4	148.4	37.8	33.8	23.0	22.8
13	178.0	165.6	36.6	36.7	20.6	22.1
14	188.8	170.2	38.0	34.3	20.1	20.2
15	192.2	177.7	35.3	38.0	18.3	21.4
16	196.0	191.9	33.6	49.1	17.1	25.6
17	200.8	196.3	34.4	40.1	17.1	20.4
18	204.0	185.3	36.2	28.1	17.7	15.1
Average.....	.....	.....	34.9	34.8	21.3	23.3

adolesence. From age ten on, the annual increments in growth in learning capacity are greater for boys, and by maturity boys have probably caught up with girls. Comparison is difficult because of selective processes at work after age thirteen. Many more boys than girls drop out of school after thirteen. Up to age thirteen, the comparative sex measures are valid. After thirteen, our figures merely compare those left in school. Further studies will have to determine the learning capacity of those who stop school.

A YEAR'S GROWTH IN LEARNING CAPACITY MADE BY THE SAME PUPILS

In the preceding experiment in card-sorting the comparison of one age with another is made on the basis of measurements of different pupils. When we say that the growth in learning capacity from one year to another is a certain amount, we do not mean that we have measured the learning capacity of the same children and found that they improved a certain amount in a year. We mean that we measured all the children of a certain age in school and compared their learning capacity with that of all the children one year older who were in school. The purpose of this experiment is to measure the improvement actually made by the same children.

Procedure of the Experiment.—Fifteen months after we had given the card-sorting experiment in a certain school, we returned and repeated the experiment for one sorting. The same card-sorting boxes were used but the compartments were numbered differently. The method of the experiment was exactly the same as at first. The bonds established in the first experiment were of no avail either as helps or hindrances because the numbers used were all different.

Since the interval was fifteen months instead of a year, only twelve-fifteenths of the improvement was considered.

The Results.—Only children of ages ten to sixteen are considered because of the small numbers younger and older who took part in the experiment.

The results are worked up in two different ways. First, the improvement made in a year is compared with the improvement from one year to the next in the first sorting of the original experiment, as shown in table V. This comparison will be found in table VIII. The improvements

shown in the norms of the preceding experiment are given first, then the per cent of improvement made by the same pupils in a year is shown, and in the last column is shown the excess of improvement made by the pupils who had had the experiment before.

TABLE VIII

COMPARING THE YEARLY IMPROVEMENT OF PRACTICED AND UNPRACTICED PUPILS, THE BASIS OF COMPARISON BEING THE NORMAL GROWTH SHOWN FROM YEAR TO YEAR IN THE FIRST SORTING AS SHOWN IN TABLE V

Age	Number cases	Normal improvement in per cent	Improvement of same pupils in per cent	Excess made by practiced pupils
		Girls		
10–11	15	11	43	32
11–12	25	3	19	16
12–13	40	14	23	9
13–14	36	8	23	15
14–15	30	.4	12	11.6
15–16	37	4	14	10
Average excess improvement				15.6
		Boys		
10–11	31	9	29	21
11–12	30	10	23	13
12–13	40	14	18	4
13–14	36	3	17	14
14–15	39	3	15	12
15–16	24	11	13	2
Average excess improvement				11

In table IX, the group taking the experiment is compared with itself. That is, their records made the first year are taken as the standards of comparison. For example,

TABLE IX

COMPARING THE YEARLY IMPROVEMENT OF THE SAME PUPILS WITH THAT OF UNPRACTICED PUPILS, THE BASIS OF COMPARISON BEING THE SCORES MADE BY THESE SAME PUPILS THE PRECEDING YEAR

Age	Improvement of unpracticed pupils in per cent	Improvement of same pupils in per cent	Excess made by practiced pupils
		Girls	
10–11	20	43	23
11–12	2	19	17
12–13	12	23	11
13–14	5	23	18
14–15	1	12	11
15–16	6	14	8
Average excess improvement..................			14.7
		Boys	
10–11	24	29	5
11–12	4	23	19
12–13	9	18	9
13–14	0	17	17
14–15	4	15	11
15–16	8	13	5
Average excess improvement..................			11

the growth of the same pupils from 11 to 12 is compared with the difference between their 11 year record and the record of the 12 year group in the first experiment. The comparison in detail is shown in the table. The excess of improvement made by the children who had had the experiment before is almost exactly the same as shown by comparison with the larger group.

Discussion and Interpretation.—Girls who had the experiment before made an improvement about 15 per cent more than the difference between the yearly groups shown in the previous norms and boys show an excess of about 11 per cent. How is this excess to be explained? The pupils simply profited to this extent by virtue of having sorted cards three times one year before. They knew better what was expected of them. They went to work immediately and lost no time. Whatever the explanations of the *causes* of the greater improvement, there can be no doubt of the *fact*. And the fact is illuminating in its theoretical bearing on all mental measurement. Previous experience may give certain pupils a decided advantage over other pupils, wholly apart from difference in original ability. By virtue of having sorted cards for only three sortings, and at one sitting, these pupils—183 girls and 200 boys—make an improvement in a year that is 11 to 15 per cent better than would have been shown by them if they had not done the experiment before.

THE RELATION OF MUSCULAR SPEED TO SCORES IN CARD SORTING

In connection with a study of the development of motor learning, the question arises as to the importance of the factor of muscular speed. We found that the card-sorting ability of children improved from year to year. How much of the improvement was due to improvement in the facility

of handling cards? If the card-sorting experiment were continued until the pupils were sorting at maximum speed, then for each year the sorting speed would be directly related to the speed with which the children could handle the cards. But in this experiment when the cards are sorted only three times, the speed of hand movement is a very small item in the score. Most of the time is consumed in finding the location of the numbers. However, we undertook to determine the speed of handling the cards by pupils of the different ages.

Procedure of the Experiment.—The experiment consisted in putting the cards into the compartments as fast as possible without reference to the numbers. The pupils put the cards in, one at a time, beginning at the left of the back row of compartments, proceeding to the right, then back to the left on the middle row; and to the right on the near row. This procedure was repeated until all the cards were distributed. The records from this experiment we shall call *distributing* time. The previous records shall be known as *sorting* time. The tapping record shown in the figure, we shall call *motor speed.*

The Results.—The results are shown in table X. Column 1 gives the ages, columns 2 and 3 give the number of cards distributed per minute, and columns 4 and 5 give the records in terms of the reciprocals of the distributing time in seconds. The results are shown graphically in figure 5, in which A represents *sorting* efficiency, C *distributing* efficiency, and B *motor speed* as determined by the tapping experiment.

The average yearly improvement in distributing speed is for girls 6.6 per cent, while their average yearly improvement in sorting is 10.4 per cent. In the case of boys, the yearly improvement in distributing is 6.9 per cent,

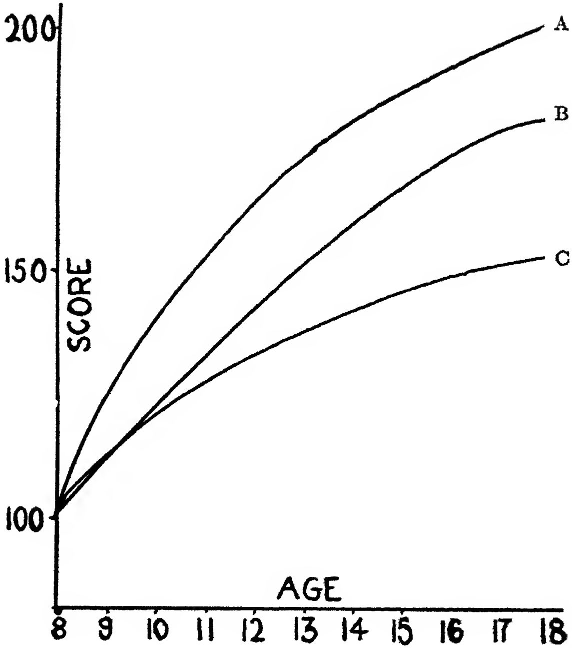

FIG. 5.—Graph A shows the yearly improvements for card-sorting, B for card-distributing, C for motor speed.

while their yearly improvement in sorting is 8.4 per cent. Their growth in sorting efficiency is clearly greater than growth in speed of movement or distributing speed.

TABLE X

SPEED IN DISTRIBUTING CARDS

Age	Cards per minute		Speed reciprocals	
	Girls	Boys	Girls	Boys
8	43	38	96	85
9	46	44	103	93
10	55	48	122	106
11	62	56	137	123
12	64	63	143	137
13	67	64	149	143
14	75	68	167	152
15	75	73	167	161
16	80	82	179	182
17	80	83	179	185
18	82	80	182	179

Discussion and Interpretation.—It will be seen that distributing efficiency improves more than mere motor speed. This is because distributing cards depends on more than mere reaction time. Ease and accuracy of movement are also involved. One can be fast and at the same time awkward. The growth in efficiency at sorting is greater still than the growth in distributing efficiency. But even if the growth in motor speed were the same as the growth in learning capacity at sorting cards, this fact would not prove that the growth in learning capacity is merely a matter of growth in speed. Experiments with adults have shown a

very low correlation between early card sorting scores and speed at distributing cards. For the first sorting this correlation is only .27. By the fourteenth sorting the correlation of distributing speed and sorting speed rises to .86, and of course finally sorting speed and distributing speed would be practically the same. It is clear that the first few records in card sorting measure chiefly the ability to learn the location of the numbers.

CHAPTER III

THE MARBLE-SORTING EXPERIMENT

Aim and Nature of Experiment.—Inasmuch as this is a sorting experiment it is like card sorting, but it consists in sorting nine colored balls instead of numbered cards. The associations are more complicated than in the preceding experiments. First, the color of a ball is associated with an animal, then the animal is associated with a position on the sorting box.

The special advantage of this experiment is that it can be given to children who can not read and who do not know their numbers. It can of course be given to people of any language and to children of any age above about two years old. It is not even necessary that children know the names of the colors. One disadvantage of the experiment is that it can not be given to children who are color-blind. It is necessary to keep a careful watch on the kind of errors made, and when a color-blind person is found, his record should be thrown out. The red-green color-blind person may put reds and greens together or either reds or greens or both with whites or blacks. Oranges and yellows are likely to be classed together. When it appears that a person may be color blind, he should be given a color-blind test, to make sure.

Method and Apparatus.—The apparatus consists of a marble-receiving box, a marble-containing box, 90 colored balls, and a color key. The marbles are taken from the marble-containing box by the subject and sorted into the

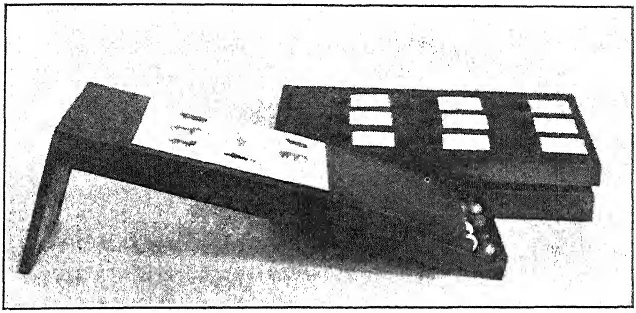

FIG. 6.—The marble-sorting apparatus. The near box is the marble-container. The rear box is the marble-receiver. On top of the container is the color key.

receiving box. See figure 6. The color key contains pictures of nine animals. Each animal is colored like one of the nine colors of the balls. That is, the nine different animal pictures correspond to the nine colors of balls. For example, the picture of the cow is green, corresponding to one color of the balls.

The procedure is as follows: The apparatus is arranged along the sides of a long table, the marble-containing box nearest the subject, and the marble-receiving box just back of it. The color key is placed face down on the containing-box. The experimenter then explains the experiment to the subjects, telling them they are to sort the colored balls as fast as possible and are to try to make no mistakes. They are told that they are to take up a marble, match it in color to the animal having the same color, then find that animal on the box and put the ball into the hole by the picture of the animal having the same color.

In the experiment as reported here, I used twenty sets of apparatus and tested twenty children at one time. I used enough trained helpers to have one for a pair of children. After I had explained the experiment each helper further explained to her two children and questioned them to make sure they understood what they were to do. When all was ready the children were told to begin and the stop-watch was started. The children sorted for five minutes, then they were sent away and the helpers counted the marbles put into the box and determined the number of errors. The records were kept in terms of total number put in and the number of errors. After the score was determined and recorded on the children's record slips, the partitions of the receiving boxes were taken out, the marbles thoroughly mixed and put back into the marble-container.

The Results.—The results shown in table XI were obtained from the pupils in grades one to eight in four schools of Sedalia, Missouri. All children in school at the time took the experiment. Records of color-blind children were excluded. The experiment has not yet been given

TABLE XI

EFFICIENCY SCORES—MARBLE SORTING

Age	Girls			Boys		
	Cases	Ave. score	Smoothed score	Cases	Ave. score	Smoothed score
6	79	31.7	31.7	77	24.7	24.7
7	94	39.0	37.5	81	36.6	34.2
8	93	42.7	43.5	87	41.7	41.7
9	94	49.3	49.5	97	45.0	47.4
10	97	53.5	55.3	103	53.1	52.0
11	93	62.8	61.1	91	55.3	56.5
12	102	66.6	66.6	103	61.2	61.2
13	98	66.4	?	88	59.0	?

to high school pupils, therefore the age norms are not valid beyond age twelve or thirteen. The results are shown graphically in figure 7.

The scores shown in table XI represent the number of marbles correctly placed in five minutes and were obtained by subtracting the number of errors from the total number of marbles put into the receiving box. In the upper grades a few of the brightest pupils would finish the experiment in less than five minutes. The experimenter noted their

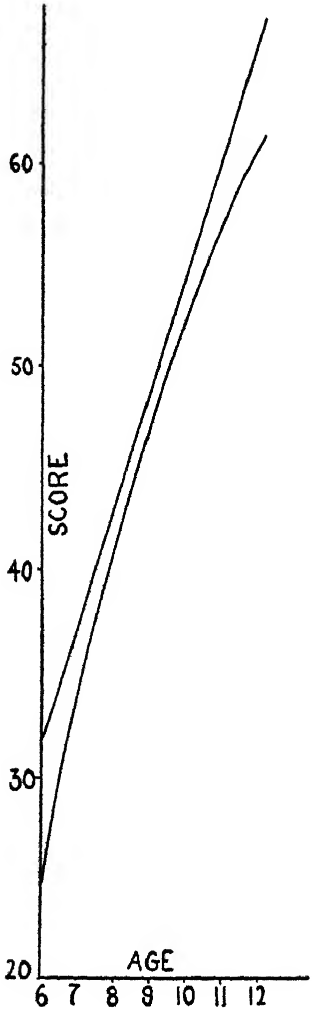

FIG. 7.—The graphs represent the yearly growths in marble-sorting capacity. The upper graph is for girls, the lower is for boys.

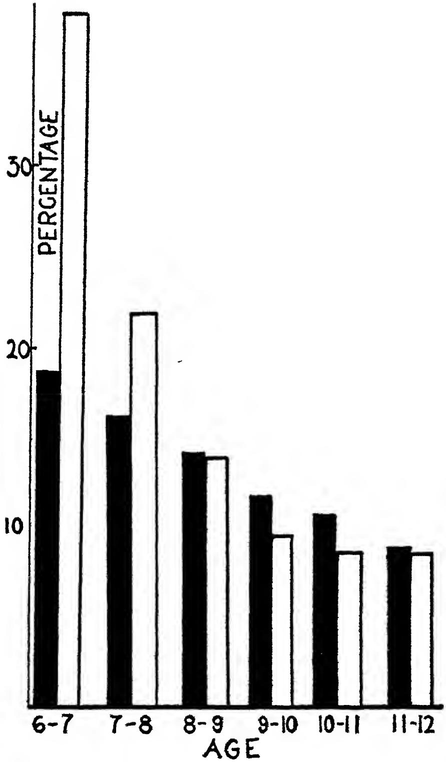

FIG. 8.—The columns show the yearly improvement in marble-sorting. The black columns are for girls; the light, for boys.

exact time and their score was reduced to a basis of five minutes.

The improvement from year to year in terms of per cent is shown in table XII, and graphically in figure 8.

TABLE XII

YEARLY IMPROVEMENT—MARBLE SORTING

Age	Per cent improvement	
	Girls	Boys
6 to 7	18.3	38.4
7 to 8	16.0	21.9
8 to 9	13.8	13.6
9 to 10	11.7	9.7
10 to 11	10.5	8.6
11 to 12	9.0	8.3

The sex differences in this type of learning are shown in months in table XIII. Column 1 gives the age of boys,

TABLE XIII

SEX DIFFERENCES EXPRESSED IN MONTHS

Boy, age, years.	Girl, years-months	Difference in months
7	6 5	7
8	7 8	4
9	8 8	4
10	9 5	7
11	10 3	9
12	11 0	12

column 2 gives the age of girls having the same learning capacity, and column 3 gives the difference in months.

Using the actual averages of table XI and computing the percentage which the boys' average is of the girls' average for each age, we get table XIV. At ages eight

TABLE XIV

SHOWING PERCENTAGE WHICH BOYS' AVERAGE SCORES AT EACH AGE ARE OF GIRLS' CORRESPONDING SCORES

Age	6	7	8	9	10	11	12	13
Per cent boys' score is of girls'	78	94	98	91	99	88	92	88

and ten, the average score made by boys almost reaches the average score made by the girls at these two ages. Taking the average of the percentages from age 6 to 13, gives for the boys a percentage of 91. On the average, then, from ages 6 to 13, the score of boys equals 91 per cent of the corresponding score for the girls.

Sex Differences in Accuracy.—In table XV is shown the average number of errors made by boys and girls at the different ages. The percentage column gives the errors expressed in terms of the percentage which the number of errors is of the average score for that age and sex.

Discussion and Interpretation.—Table XI shows that from age 6 to 13, boys and girls more than double their efficiency at sorting colored balls and associating colors with pictures of animals. Girls are better learners than boys in this experiment at every age from six to thirteen. Up to age twelve girls not only make fewer mistakes but a smaller percentage of mistakes. At age thirteen the average number of errors for girls is slightly greater than for boys, but the percentage is less even here.

Table XII and figure 8 show that boys improve more from six to seven and from seven to eight than do girls.

The experiment proves very difficult for six-year-old boys. As a result the first two years show great improvement for boys. After age eight, the yearly improvement of girls is slightly greater than that of boys.

TABLE XV

Age	Boys		Girls	
	No. errors	Per cent of score	No. errors	Per cent of score
6	4.12	16.6	3.54	11.2
7	4.74	12.9	3.96	10.2
8	3.88	14.1	4.85	11.4
9	6.92	13.4	5.61	11.4
10	7.51	14.1	6.44	12.0
11	8.66	15.6	8.03	12.8
12	8.86	14.5	8.63	13.0
13	9.75	16.5	9.78	14.7
Average....	7.05	14.7	6.23	12.1

From 12 to 13 our results show no improvement in this experiment. In fact, there is a small falling off. There is some selection at age 13. Some of the brightest pupils have already passed on to high school. On the other hand doubtless some of the dullest have stopped school. There are only four fewer cases of girls at thirteen, but fifteen fewer boys than for twelve. We are unable to say what the course of development of learning capacity for this type of learning is after age twelve.

CHAPTER IV

THE SUBSTITUTION EXPERIMENT

Nature and Aim of the Experiment.—The substitution experiment measures a very simple type of learning, the association of a digit with a letter. Since the pupils already know the letters and the digits, the learning consists in associating certain letters with certain digits. The experiment has the advantage that it is easily explained to the pupils, and can be easily and quickly given. The scoring is simple, and can be quickly done.

Material and Method.—The material used was the Pyle digit-symbol substitution test blanks. At the top of the test sheet is a key which gives the scheme of association. Below the key are two columns of numbers with blank squares following. In the blank squares, the pupils are to write the letters which correspond to the digits of the numbers on the left. The experiment is carefully explained to the pupils. They are told to see how many of the squares they can fill in according to the key at the top of the test sheet. The sheets are passed, two to each pupil, and placed face down on the desks and are not to be turned over till the experiment begins. When it is clear that all pupils understand what they are expected to do, the signal is given to turn over the sheet and begin. Five minutes are given for the experiment. At the end of five minutes all work is stopped and the papers are collected. The experimenter makes sure that every sheet is properly marked with the name, age, sex, and grade of the pupil.

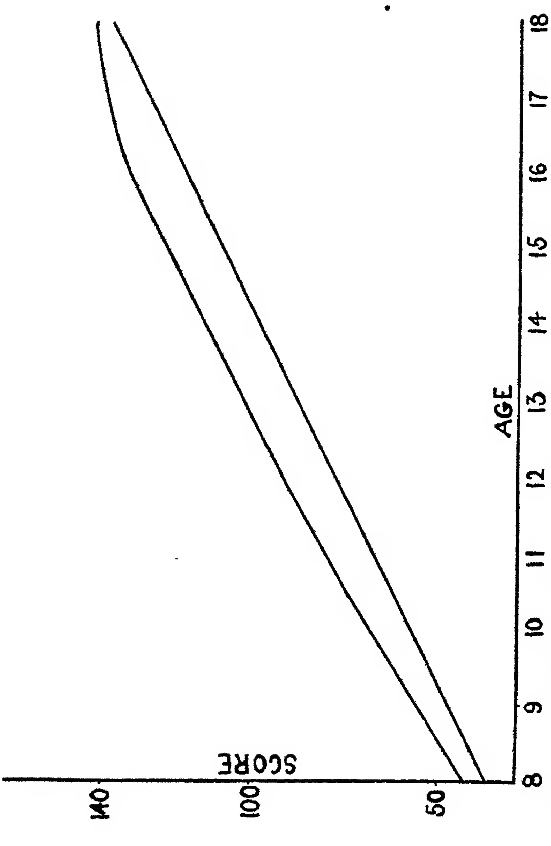

FIG. 9.—The graphs represent the yearly growth in the substitution experiment. The upper graph is for girls; the lower, for boys.

Results.—The age and sex norms are shown in table XVI, and graphically in figure 9. The efficiency scores shown in the table represent the number of substitutions correctly made in five minutes.

TABLE XVI

SUBSTITUTION SCORES

Age	Cases		Learning efficiency		Scores smoothed	
	Girls	Boys	Girls	Boys	Girls	Boys
8	265	260	44.5	38.0	42.5	37.5
9	416	355	54.1	48.5	56.0	47.5
10	455	488	68.7	58.7	68.2	57.5
11	461	519	79.7	66.7	80.2	67.5
12	524	473	91.6	76.9	91.6	77.5
13	504	476	102.3	84.9	102.3	87.5
14	440	398	112.3	95.9	112.3	97.5
15	374	332	122.0	109.2	122.3	107.5
16	285	245	133.7	116.6	133.3	117.5
17	213	131	138.7	128.1	138.7	127.5
18	86	52	142.0	122.1	142.0	137.0

Table XVII shows the actual yearly improvement and this improvement expressed in terms of per cent which the growth is of the score of the preceding year.

The sex differences are shown reduced to months, in table XVIII. The first column gives the age of boys. The second column gives the average age of girls having equal learning capacity. The third column gives the difference in months between the average ages of girls and boys having equal learning capacity.

TABLE XVII

SUBSTITUTION—YEARLY GROWTH

Age	Girls		Boys	
	Actual growth	Per cent	Actual growth	Per cent
8 to 9	13.5	31.7	10	26.6
9 to 10	12.2	21.8	10	21.1
10 to 11	12.0	17.6	10	17.4
11 to 12	11.4	14.2	10	14.8
12 to 13	10.7	11.7	10	12.9
13 to 14	10.0	9.7	10	11.4
14 to 15	10.0	8.9	10	10.3
15 to 16	11.0	8.9	10	9.3
16 to 17	5.4	4.1	10	8.5
17 to 18	3.3	2.4	9.5	7.4

TABLE XVIII

SUBSTITUTION—SEX DIFFERENCES EXPRESSED IN MONTHS

Boys, Age		Girls, Yrs.	Mos.	Difference in Months
9	=	8	4.4	7.6
10	=	9	1.5	10.5
11	=	9	11.4	12.6
12	=	10	9.5	14.5
13	=	11	7.9	16.1
14	=	12	6.8	17.2
15	=	13	6.2	17.8
16	=	14	5.9	18.1
17	=	15	7.6	16.4
18	=	16	7.4	16.6

In table XIX are shown the percentages which the average boys' scores for the different ages are of the corresponding girls' scores.

TABLE XIX

PERCENTAGE COMPARISON OF BOYS AND GIRLS IN SUBSTITUTION

Age	8	9	10	11	12	13	14	15	16	17	18
Per cent boys' score is of girls' score	85	90	85	84	84	83	85	90	87	92	86

Discussion and Interpretation.—The scores in this experiment are obtained from 7752 pupils, an average of 366 girls for each age, and 339 boys for each age. It will be noticed that the annual improvement is almost the same from year to year. The growth curve is therefore practically a straight line for girls up to age sixteen, and for boys up to age seventeen. Both boys and girls make a steady improvement from age eight to eighteen. Whether the continued growth shown through adolescence is due merely to the elimination from school of the poorer learners, we can not say. Certainly for pupils in school there is a continued improvement in ability to do the substitution experiment up to age eighteen. A study of the graphs shows that improvement begins to fall off earlier for girls than for boys. Probably at maturity the boys have caught up with the girls.

CHAPTER V

THE MIRROR DRAWING EXPERIMENT

Nature and Aim of the Experiment.—This experiment is different from all the others considered in this study, in that it involves trial-and-error learning. In the other experiments, while motor elements are involved, the pupil knows how to make the movements and can make them at will. In the mirror experiment, the pupils *can not at first make the desired movements* from the stimulus that is given. The learning consists in getting the stimuli to pass over into the desired movement. Learning to write and draw in the early years of life involves the same learning principles.

In the mirror experiment the problem set the child is to draw lines from certain points to certain other points, the stimuli being reflected from a mirror in front of the subject. This provides a situation not met before by the child in just this form. In fact the experiment involves to some extent the undoing of habits already formed.

Apparatus and Method.—The apparatus consists of an adjustable blind to conceal the hand from direct vision but which makes it possible for the subject to see his hand as reflected in the mirror, which is held in a vertical position by metal posts at the back of the board to which the shield is attached. The mirror drawing sheets contain series of dots arranged in a large outer circle and a smaller inner circle. These are numbered from 1 to 24, and the subject must start at dot number 1 and proceed to 2, then to 3,

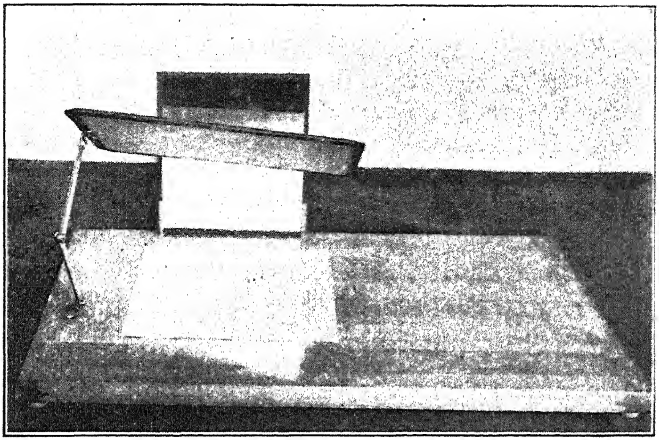

Fig. 10.—The mirror-drawing apparatus.

then to 4, and so on around back to number 1 again. Joining the dots from 1, back around to 1 again involves the making of 24 lines. In the experiment as given to school children a time limit of five minutes was set and the score for each child was the number of lines successfully drawn. Each child was provided with several test sheets and was told to keep on working till told to stop. It was explained to the subjects that they should *join the dots* and should not leave a dot till they had actually touched it. The time can be kept by means of a stop-watch or ordinary watch, but an interval timer is best. The apparatus is illustrated in figure 10.

Results.—While I have not given this experiment to a large enough number of school children to establish reliable

TABLE XX

SHOWING AGE AND SEX AVERAGES FOR BOYS AND GIRLS IN MIRROR DRAWING EXPERIMENT

Age	Boys			Girls		
	No. cases	Ave.	Smoothed	No. cases	Ave.	Smoothed
9	31	5.8	5.8	37	5.7	4.5
10	65	10.0	8.0	44	6.0	6.0
11	55	10.2	10.2	50	9.0	9.0
12	63	14.5	12.5	60	12.6	12.6
13	51	14.9	14.9	50	15.3	15.3
14	35	14.1	17.4	39	18.0	18.0
15	24	15.6	20.0	33	22.7	22.7
16	22	23.6	23.2	19	21.5	29.5
17	11	25.0	25.2	24	34.9	34.9

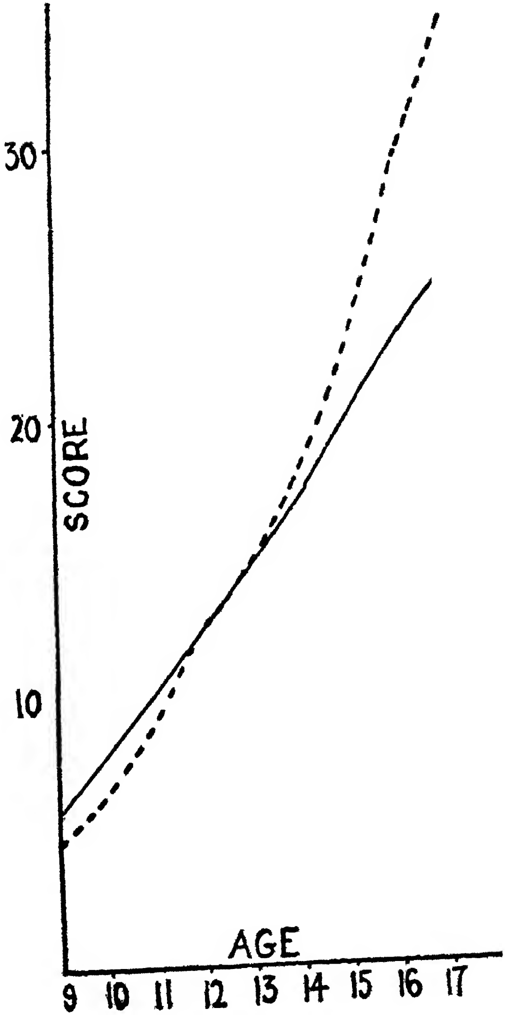

FIG. 11.—The growth curves for mirror drawing. The solid line is for boys, the dotted line is for girls.

age and sex norms, the number of subjects tested is sufficient to show the general course of development for this type of learning. In table XX are shown the scores actually obtained and also the scores smoothed to show the probable norms. The raw scores of the girls make a fairly smooth curve, but the curve made from the scores of the boys is very irregular. The graphs of figure 11 therefore show considerable smoothing in the case of boys but very little for the girls.

In table XXI is shown the average yearly improvement of boys and girls.

TABLE XXI

SHOWING AVERAGE YEARLY IMPROVEMENT FOR BOYS AND GIRLS IN THE MIRROR DRAWING EXPERIMENT

Age	Per cent improvement	
	Boys	Girls
9–10	38.0	33.3
10–11	27.5	50.0
11–12	22.5	40.0
12–13	19.2	21.4
13–14	16.8	17.6
14–15	14.9	26.1
15–16	16.0	29.9
16–17	8.6	18.3

Discussion and Interpretation.—The results shown by this experiment are different in certain important aspects from those of the other experiments considered in this book. The experiment is too difficult for the younger children.

I found it impossible to do much with it below the fourth grade. Up to age twelve the boys are superior at this type of learning. But if my meager data are anywhere near the truth, girls excel after age twelve. This is just about the reverse of the results of all the other experiments, particularly in motor learning, for we have found the girls to excel especially in the earlier years.

The scores show a very great improvement from year to year in this type of learning. The average yearly per cent of improvement in the mirror experiment is 20.4 for boys and 30.1 for girls, while in card sorting for the same period boys made an average yearly improvement of only 7.7 per cent and girls of 6.4 per cent. It may be mentioned also that the learning curve for this experiment plotted to show the improvement of a person made in a given time, as a half-hour, rises very fast, just as the improvement from year to year is great. The point is, there is a similarity between the yearly development curve due to age and the learning curve due to practice.

CHAPTER VI

THE MANTHANOMETER EXPERIMENT

Purpose and Nature of the Experiment.—The manthanometer experiment here discussed is a study of the development of a complicated form of sensori-motor learning. The apparatus used is illustrated in figure 12. The experiment consists in sorting colored balls, and balls of two sizes, simultaneously. The stimulus is supplied by the use of a Ranschburg apparatus on which is placed a disc. On the disc arranged in two circles are painted the stimuli in the form of small colored circles. These small circles are of two sizes. The subject presses an electric key in circuit with the Ranschburg apparatus. When the circuit is closed the disc turns bringing a color into view. The color indicates the color of marble to be taken by the right hand. The size of the colored circle indicates whether the left hand is to get a large or a small marble. The subject, having in his right hand a marble of a certain color, and in his left hand a white marble, large or small, deposits them according to previous directions, and pedals according to previous directions. The compartments of a drawer below receive the marbles, and all the errors are evident. For full directions and explanations the reader is referred to the author's *Laboratory Manual in the Psychology of Learning*.

This experiment differs greatly from all the others considered in this study. The subject must keep in mind some rather complicated instructions. He must keep going several simultaneous processes. The experiment requires

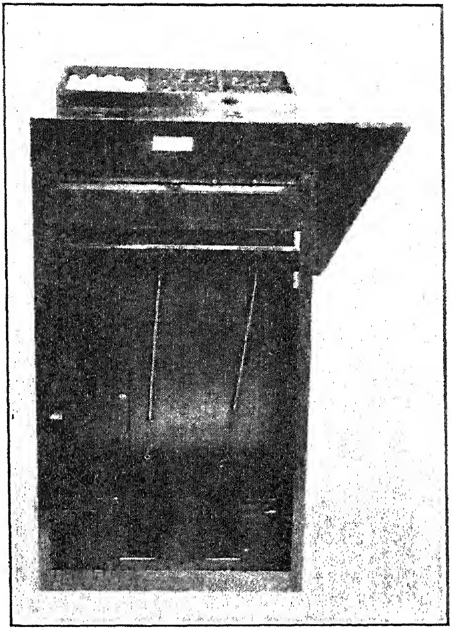

Fig. 12.—The manthanometer.

in a rather high degree what is commonly called attention or concentration. In my opinion this experiment measures not only general learning capacity but a specific type of ability, the type required in operating complex machinery, such as an automobile. A person capable of carrying on only one process at a time does not succeed well at this experiment.

The Results.—This is an individual experiment and requires considerable time. A half hour is ordinarily required for a single sorting, including the time required for explanations, counting the errors and computing the efficiency scores. Because of the great amount of time required in this experiment I am not yet able to give

TABLE XXII

SHOWING THE APPROXIMATE AGE AND SEX NORMS FOR ONE AND TWO SORTINGS OF THE MANTHANOMETER

Age	First sorting		Second sorting		First and second combined	
	Boys	Girls	Boys	Girls	Boys	Girls
9	9.7	11.9	12.0	15.0	21.7	26.9
10	10.7	12.6	14.1	16.5	24.8	29.1
11	11.7	13.3	16.0	17.7	27.7	31.0
12	12.7	14.1	17.6	18.7	30.3	32.8
13	13.6	14.8	19.0	19.7	32.6	34.5
14	14.4	15.4	20.3	20.7	34.7	36.1
15	15.3	16.0	21.5	21.7	36.8	37.7
16	16.3	16.5	22.8	22.5	39.1	39.0
17	17.0	17.0	24.0	23.2	41.0	40.2
18	17.7	17.5	25.0	23.5	42.7	41.0

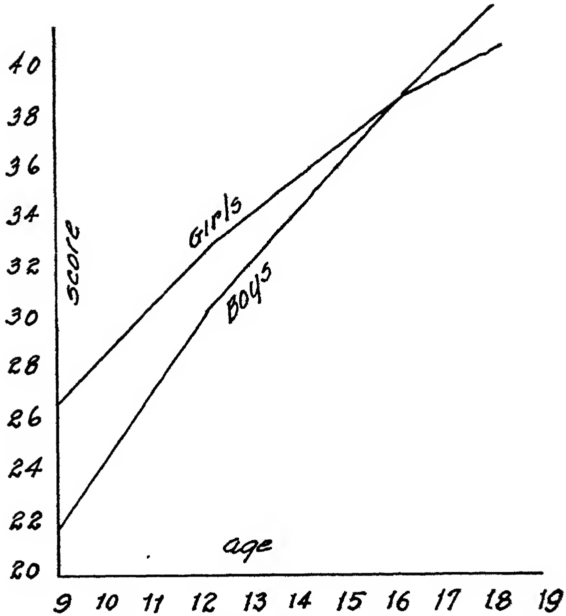

FIG. 13.—Growth curves showing the yearly improvement of learning capacity in the manthanometer experiment.

definite age and sex norms. On the basis, however, of the results from four hundred white children of the ages 9 to 18 I can give tentative norms which can not be far from correct. I am reasonably sure that the graphs of figure 13 represent the general course of development for this type of learning, and table XXII shows the tentative norms which are approximately correct. The efficiency scores are obtained as follows: the number of errors is subtracted from 96, the total number of marbles. The remainder is multiplied by 60 and the product divided by the number of seconds required for the sorting. The efficiency score, therefore, represents the number of marbles correctly placed in a minute.

Eighty-two university juniors, mostly girls, make an efficiency score on the first sorting of 19.4; on the second, of 25.4; on the two combined, of 44.8

Discussion and Interpretation.—I hesitate to draw conclusions from the results of this experiment until I have measured a thousand more children. However, while further study may raise or lower the indicated age and sex norms, it is not likely to change materially the general course of development which the figures here show, nor the sex relationships, for while I have measured only a few of each age for each sex, those measured were unselected.

If the previous experience of the children favors either sex, one would expect it to be the boys, but in spite of such advantage (if it exists) the girls excel the boys apparently to age 16. My data at present would indicate that after age 16, the boys excel.

It is impossible in this experiment, at present, to apportion properly the relative effects of age, sex, specific ability, and general learning capacity. It may be, for example, that if we make all other conditions equal, boys

excel in this type of learning. The girls excel in the early ages because of their being further developed than the boys. With passing years, the boy's experience with machinery and his greater ability for this type of process enable him to surpass the girl. But these statements are entirely hypothetical.

Whatever may be the truth in regard to the explanation of the scores, the experiment will prove successful in comparing the members of any group for this type of learning.

CHAPTER VII

IDEATIONAL LEARNING

Aim and Nature of Experiment.—In an ideational learning experiment it is best to grade the material. The content and language should be adapted to the age of the pupils. We have therefore used material of three grades of difficulty, one for the lower grades, one for the upper grades, and one for the high school. There are two tests of each grade of material. The high school tests are called A and B; the tests for grades 6, 7, and 8 are called C and D, and tests for grades 4 and 5 are called E and F.

In the five types of learning previously discussed, the learning was of the kind usually called habit-formation. In the experiment discussed in this chapter the learning is ideational. It is the kind of learning involved in knowledge-getting. The association is between ideas. This experiment, therefore, is designed to measure the type of learning involved in most school studies, in which the pupils read books to get information, as in geography, history, and science.

Material and Method.—The material consists of printed test sheets A, B, C, D, E, and F, already mentioned. If experiment A, for example, is being given, the test sheets A are distributed and placed face down on the desks. The pupils are told that they will be given five minutes to read and study the story printed on the test sheet. They are to try to learn the story as completely as possible, not the words but the ideas. They are told that after they have

studied the story for five minutes they will be examined on it to see how much they have learned. It is emphasized that the pupils are to learn the facts not the words. They are to study the story as they would a lesson. When the five minute study period is up the test sheets are collected and the questions are distributed. The questions are answered on separate sheets so that the questions can be collected and used again. The pupils are given five minutes in which to answer the questions. They should number their answers to correspond to the questions. Copies of the tests and questions are shown herewith on pages 62 to 76. With the questions, the correct answers and the scoring are indicated.

A

Practically everything you eat, taste, wear, smell, and see has resulted in some way from the ingenuity of chemists. The story of chemistry is like an endless chain—it might begin anywhere, and need never end.

Just now you were looking out of the window. That glass is a product of chemistry. Glass is made of soda, lime and sand. A mixture of these substances is melted down to a bright red heat. A big molten ball of it is then gathered on the end of a blowpipe. Air is forced through the pipe and the ball becomes a bulb, the bulb becomes a long cylinder. At the right temperature, the cylinder is laid on a table and slit. The cylinder flattens out. That is window glass.

In the hall door of your home or in your office there is a pane of plate glass. This is made by casting the molten glass. It is first pressed as smooth as possible, then ground still smoother, then polished. It is a product of comparatively recent years, chiefly due to American ingenuity.

The desk at which you work was made with steel tools. The steel of which these tools were made is, of course, a chemical composition. And these wood-cutting tools had first to be made with other tools that could cut steel.

Once this process was very slow and expensive. The steel tool used by a lathe worker in cutting out other tools would get red-hot and lose its "temper," so that it could not cut. Then the lathe worker lost his temper, too! For he had to stop, resharpen his tools, and waste a great deal of time. Chemists added certain rare metals, such as tungsten or molybdenum, to the iron that makes ordinary steel, and as a result of that and of other discoveries, we have "high-speed steel."

This steel is so expensive that tools are tipped with only a fraction of an inch of it in much the same way as our finest gold pens are tipped with a platinum iridium alloy to keep them from wearing out.

This steel tip is many times as efficient as ordinary steel. Without high-speed steel you could not have such cheap typewriters, farm implements, and automobiles; for this product has revolutionized the whole metal industry.

QUESTIONS AND ANSWERS

	Score
1. What has resulted from the ingenuity of chemists? Practically everything we *eat*, *taste*, *wear*, *smell* and *see*.	5
2. What is the story of chemistry like? An *endless chain.*	1
3. What is glass made of? *Soda, lime, sand.*	3
4. What is first done with the mixture? *Melted down* to *bright red heat.*	2
5. What next? *Molten ball gathered on end of a blowpipe.*	1
6. What then? *Air is forced through the pipe.*	1
7. What is done with the cylinder? *Laid on the table and slit.*	2
8. What is the final product? *Window glass.*	1
9. How is plate glass made? *By casting the molten glass.*	1
10. What are the three steps after it is cast? *Pressed smooth*, *ground*, and *polished.*	3

		Score
11.	What nation is responsible for the plate glass process? *America* (U. S.).	1
12.	How are "high speed steel" tools made? *By tipping with or adding tungsten or molybdenum.*	2
13.	What is the chief result to us of "high speed steel" tools? *Cheaper* implements.	1
	Total score possible	24

B

In the room where you are reading there is probably a tungsten electric light bulb. Doubtless you remember what a big improvement the first tungsten filament seemed to be, only a few years ago, when it came to displace the carbon filament in our electric bulbs. The carbon filament was inefficient and burned up too much power for the light it gave. So chemists had to seek a new substance that could be raised to a higher temperature, receive a higher current, and so give more light.

After trying various substances, they tried tungsten. This is a metal which we get as an oxide, like a powder, just as we get iron. The first difficulty was to make tungsten into a workable metal. This was solved by pressing the tungsten powder together with a "binder," just as a confectioner fastens popcorn balls together with gum arabic.

You remember how frail the filaments made of this tungsten metal were at first? If you had examined one of these filaments under a microscope, you would have seen that it looked something like a string of peas fastened together with the gluelike binder. A very slight jar was sufficient to break the filament.

So chemists set to work to make tungsten into a ductile metal that would bend and could be drawn out without breaking. Here they met a great difficulty, because the tungsten would form into crystal-like parts that were so brittle that the metal chipped instead of bending. Finally it was made ductile by the process of "swaging." Electricity is sent through a bar of tungsten until the bar becomes white-hot. Then the bar is passed through a rapid ham-

mering process, with hammers beating the white-hot metal from all directions. This breaks down the crystals, and the bar of tungsten becomes a ductile metal.

After swaging, the tungsten is in the form of a metal bar about fourteen inches long and three-eighths of an inch square. To get it into a filament for your electric light bulb, it has to be passed through a series of dies. After passing through each die, the bar is smaller around and longer, until finally it is drawn out into a wire. When it has passed through the last tiny die, the original fourteen-inch bar has become a wire THIRTY-NINE AND SIX-TENTHS MILES in length. In an ordinary electric light bulb, there are about sixteen inches of this wire.

QUESTIONS AND ANSWERS

SCORE

1. What kind of electric light bulbs were in use up to a few years ago?

Carbon. 1

2. Why was it a poor light?
Inefficient; uneconomical—used too much power for the light it gave. 2

3. What sort of substance did chemists have to find to make a good bulb?
Raise to a higher temperature; receive a higher current; so as to give more light. 3

4. What was the substance which they finally found?
Tungsten. 1

5. In what form is the metal found?
Oxide; like a powder. 2

6. What was the first scheme for using this metal?
Press together; with a binder. 2

	Score
7. Why was the method not satisfactory? *Slight jar would break—broke too easily.*	1
8. What trouble did the chemists encounter in making the metal ductile? *Tungsten formed crystals.*	1
9. How was the difficulty overcome? *Swaging; electricity sent through till white hot—hammers beating from all sides.*	2
10. After swaging, what is the size of the piece of metal used? 14 *inches long and* $\frac{3}{8}$ *of an inch square.*	2
11. How is the bar made into fine wire? *Passed through a series of dies.*	1
12. How long is the wire made from it? $39\frac{6}{10}$ *miles.*	1
13. How much wire is in one bulb? 16 *inches.*	1
Total score possible	20

C

Perhaps at some time in your life you've stood in front of a lion's cage at a circus, watching the pacing beast within, and speculating upon what is happening in the mind of the shifting, uneasy creature.

You think it is easy to read that mind. He wants to get out. You are sure you see murder in those deep eyes, that only one thought occupies that bestial brain—to escape those steel bars, to break forth upon the humans he hates, to destroy, to devour—

Just a moment, please! That's very dramatic and exciting. The trouble is you are entirely wrong! If that lion is thinking at all he's wondering whether he's going to get a bone for breakfast the next morning, or whether it will be lean meat. As for escaping—why should he leave a good home and make a lot of trouble for himself? That pacing and leaping is merely obedience to a natural law, which commands that he take a certain amount of exercise. Queer, but it's true—the escape of an animal about a circus is often funnier than it is serious.

There must be a reason; and there is. As a rule, the animal that you see in the circus isn't a product of the jungle. He probably wouldn't recognize his "native heath" if he saw it. He was born in a cage, he was reared in one, and he knows absolutely nothing about the other life.

True, give a lion or tiger or leopard even a day in the open country, and he will become like an ordinary wild animal. He will become the savage beast his instincts command him

to be. But he can't do this in a few minutes. The result is that when he does escape, through innate animal curiosity which leads him to investigate why his cage door should be open instead of closed, or why a lock or bar should give beneath his weight when he leaps, he finds himself in an unkind, noisy, excited sphere, full of troubles and annoyances, and he wishes he never had wandered from the old fireside.

A beast may be mean within an arena. He may even be a killer. Yet, once on the outside, he may be a poor, befuddled thing, happy to find again the open door leading to his cage.

QUESTIONS AND ANSWERS

	Score
1. What is a caged lion probably thinking about? *Wondering whether he will get a bone for breakfast or whether it will be lean meat.*	2
2. Why does he pace and leap? *Obedience to natural law, which commands that he take exercise.*	2
3. Where do show animals come from? *Born in a cage and raised in a cage.*	2
4. How long would it take them to become like ordinary wild animals if they were set free in the open country? *A day.*	1
5. How do animals happen to get out of their cages? *Curiosity leads them to investigate; they try the open door or break through the bars.*	4
6. What do they wish most when they do escape? *That they had never wandered away.*	1
7. How do they feel when they are outside? *Like poor befuddled things, happy to find again the open door to the cage.*	2
Total score possible	14

D

Talk to the animal trainer, and he will tell you that as a rule it is not the maliciousness of an escaped animal which causes trouble; it's the panic of the crowd about him, and the fright of the animal himself. For the animal only wants to get back "home."

In Riverside, California, several years ago, during the circus season, the herd of elephants got panicky and decided to run. Old Mama, the leader, crashed through a barber shop, taking with her, draped over her shoulders, the mug rack which hung at one end, and distributing along the street the vari-colored shaving-soap receptacles with their gaudy lettering and resplendent flowers, while the rest of the herd, trumpeting and bellowing, clattered along in the rear. From there, the course led down the street, where, a bit tired, Mama stopped at a fruit stand, the rest of the herd nudging up beside her, while the proprietors yelled for the police—and departed.

The oranges and apples were great. Mama enjoyed 'em. Also, Alice and Floto and Frieda and the rest of the bulky runaways. In the rear, the crowd recovering a bit from its fright, began to close in. Just then, however, Mama happened to notice that within the store hung a beautiful bunch of bananas. So she went in, taking the door with her. After that—a new panic, for the floor was breaking and an elephant hates an unsound footing. So she and all the rest of the herd went out again—through the wall opposite where the door had been.

Out into the country the herd trotted. Later a yelping livery stable owner brought wild word that a flock of elephants was eating up everything in his barn!

There the animal men found them, happy and squealing and grunting as they answered the shout of "Mule up" and trudged back once more to the circus. They were through with their panic. They had found the smell of fresh hay—which would indicate to them the menagerie—in a livery stable, and there they stopped. It wasn't exactly home, but it was a good substitute.

QUESTIONS AND ANSWERS

SCORE

1. In case of escaped wild animals, what causes the trouble?
Panic of the crowd and fright of the animal. 2

2. What do such wild animals want?
Want to get back home. 1

3. Where did the incident related take place?
Riverside, California. 2

4. What did the panicky elephants do?
Decided to run. 1

5. Which one was the leader?
"Old Mama." 1

6. Where did she go first?
Crashed through a barber shop. 1

7. What did she do there?
Took mug rack on her shoulders and scattered various shaving articles. 2

8. What did the rest of the herd do?
Trumpeting and bellowing they clattered along in the rear. 3

9. Where did they go next?
Down the street, to a fruit stand. 2

10. What did they do?
Stopped—gathered up together and ate the fruit. 2

		Score
11.	What did the proprietor do?	
	Yelled for the police and departed.	2
12.	Why did the leader go inside?	
	She saw a bunch of bananas.	1
13.	Why did she go out?	
	Floor started to break and elephants hate unsound footing.	2
14.	Where did they go next?	
	Out into the country.	1
15.	Where did the showmen find them?	
	In a livery stable.	1
16.	What term did the men use in driving the elephants?	
	"Mule up."	1
17.	Why had they stopped at this place?	
	Smelled the fresh hay which seemed like the menagerie or a good substitute for home.	2
	Total score possible	27

E

There hung just inside my window a box of strings, and for two or three days, no matter how many I put into it, when I went to look the next time none could be found. I had talked to the little girls and scolded the little boys in the house, but no one knew anything about the matter, when one afternoon, as I was sitting there, a beautiful bird with a yellow breast fluttered down from the willow tree, perched on the window sill, cocked his saucy head, winked his bright eye, and dipped his naughty little beak into the string box and flew off with a piece of pink twine.

I sat as still as a mouse to see if the little scamp would dare to come back; he did not but he sent his wife, who looked me squarely in the eye, and took her string without being a bit afraid.

After they got the string they began to work busily. They had already chosen a place for their nest, a place far out of sight of snakes and hawks and cruel cats, and out of reach of naughty boys with their sling-shots. They did not need nails and hammer for their work, but claw and bill were all the tools they needed, and yet what beautiful carpenter work they did!

The nest was strongly tied to three slender twigs, and was carefully and closely woven, so that it could scarcely be torn apart. It had a lovely lining of duck's feathers and lamb's wool. And when this lining was put in, all was ready for the five little precious eggs.

QUESTIONS AND ANSWERS

SCORE

1. What hung inside the window?
Box of strings. 1

	Score
2. How long had the string been disappearing?	
For two or three days.	1
3. What persons knew where the string had gone?	
No one knew.	1
4. What kind of bird took the string?	
A beautiful bird with a yellow beak.	2
5. How did the bird act when he came for the string?	
Shy—afraid.	1
6. What bird came next?	
Mother bird—wife.	1
7. Was the second bird afraid?	
No.	1
8. What kind of place was chosen for the nest?	
Safe place out of sight and reach of snakes, hawks, cats, naughty boys.	5
9. What kind of tools did the birds use in making the nest?	
Claw and bill.	2
10. How was the nest woven?	
Closely and carefully.	2
11. How was the nest lined?	
With duck's feathers and lamb's wool.	2
12. How many eggs were to be laid in the nest?	
Five (5).	1
Total score possible	20

F

The Maple-tree lived on the edge of the wood. Beside and behind her the trees grew so thick and tall that there was plenty of shade at her roots; but as no one stood in front, she could always look across the meadows to the brown house where Maggie lived, and could see what went on in the world.

After the cold winter had gone by, and the spring had come again, the Maple-tree sent out thousands of tiny leaf-buds, that stretched themselves, and grew larger day by day in the warm sunshine. One little bud, on the end of a tall branch, worked so hard to grow that by and by he finished opening all his folds, and found himself a tiny pale green leaf.

He was curious, as little folks generally are, and as soon as he opened his eyes wanted to see everything about him. First he looked up at the blue sky overhead, but the sky only looked quietly back at him. Then he looked across the meadows to where Maggie lived. But Maggie was at school and the house was still.

Then he gazed far down below him on the ground; and there, just beneath, was a little Violet. She had uncurled her purple petals a few days before, and was waiting to welcome the first leaf-bud that came out.

So when the Maple-leaf looked down, she smiled up at him and said, "Good-morning." He answered her politely, but he was very little, and did not know quite what to say, so he did not talk any more that day.

The next morning they greeted each other again, and soon they grew to be good friends and talked together very happily all day.

QUESTIONS AND ANSWERS

	Score
1. In what part of the woods did the Maple-tree grow? *Edge.*	1
2. On which sides of the Maple-tree did the trees grow thick? *Beside and behind (all sides but in front).*	2
3. On which side did Maggie live? *In front.*	1
4. What did the Maple-tree do after winter had gone? *Sent out thousands of leaf buds—budded.*	1
5. What did one little bud do? *Worked hard to grow, opened all his folds and became a green leaf.*	3
6. What did the little leaf look at first? *The blue sky.*	1
7. Where did it look next? *Across the meadow to the house where Maggie lived.*	2
8. Where was Maggie now? *At school.*	1
9. What did the leaf see on the ground? *A Violet.*	1
10. What did the Violet say to the Maple-leaf? *Good morning.*	1
11. Why did the Maple-leaf not talk much to the Violet at first? *He was very little and did not know what to say.*	2
12. What did the Maple-leaf and Violet do the next morning? *Greeted each other again—spoke again.*	1
13. When did they become good friends? *Soon—not very long afterwards.*	1
14. What did they do then? *Talked together happily all day.*	3
Total score possible	21

Results.—The results for the separate tests are shown in tables XXIII, XXIV, and XXV.

TABLE XXIII

TESTS E AND F. AVERAGE SCORES MADE BY BOYS AND GIRLS IN GRADES 4 AND 5

Age	Sex	No. cases	Test E	Test F	E and F combined
9	Girls	44	6.9	7.1	14.0
	Boys	32	5.0	5.7	10.7
10	Girls	46	7.4	7.9	15.3
	Boys	51	6.6	7.9	14.6

TABLE XXIV

TESTS C AND D. AVERAGE SCORES MADE BY BOYS AND GIRLS IN GRADES 6, 7, AND 8

Age	Sex	No. cases	Test C	Test D	C and D combined
11	Girls	52	5.2	10.8	16.0
	Boys	50	5.0	9.1	14.1
12	Girls	79	5.4	11.0	16.4
	Boys	46	5.2	10.5	15.7
13	Girls	51	5.6	11.2	16.8
	Boys	53	5.4	10.7	16.1

TABLE XXV

TESTS A AND B. AVERAGE SCORES MADE BY BOYS AND GIRLS IN HIGH SCHOOL

Age	Sex	No. cases	Test A	Test B	A and B combined
14	Girls	66	9.0	6.5	15.5
	Boys	50	10.0	6.5	16.5
15	Girls	94	9.6	6.6	16.3
	Boys	59	10.6	7.8	18.5
16	Girls	64	10.5	8.6	19.1
	Boys	56	11.3	8.0	19.3
17	Girls	64	11.2	9.1	20.3
	Boys	31	14.1	11.0	25.1

In order to be able to show the yearly development of this type of learning it was necessary to find the relative difficulty of the three different grades of tests. This was done by giving tests E, F, C and D to the same grades, the fifth and sixth; and tests C, D, A, and B to grade 8. By so doing it was found that E and F grades could be converted into C-D grades by multiplying E-F combined by .325; and that A-B could be converted into C-D grades by multiplying A-B combined by 1.25. The ideational learning scores, thus converted are shown in table XXVI graphically in figure 14.

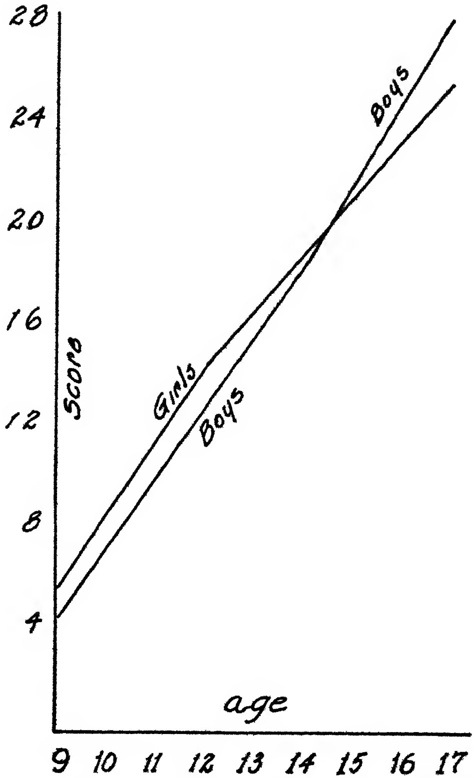

FIG. 14.—Graphs showing the yearly development in ideational learning.

TABLE XXVI

COMBINED SCORES OF A, B, C, D, E AND F—SMOOTHED

Age	Girls	Boys
9	5.4	4.4
10	8.5	7.4
11	11.0	10.2
12	14.4	13.2
13	16.9	16.0
14	19.2	18.5
15	21.2	22.0
16	23.5	25.2
17	25.5	28.4

The annual growths expressed in percentages are shown in table XXVII.

TABLE XXVII

GROWTH IN IDEATIONAL LEARNING EXPRESSED IN PER CENT

Age	Per cent of improvement	
	Girls	Boys
9 to 10	57	68
10 to 11	29	38
11 to 12	31	30
12 to 13	17	21
13 to 14	13	16
14 to 15	10	19
15 to 16	11	15
16 to 17	9	13

The sex differences expressed in months are shown in table XXVIII. It will be seen that boys have higher scores for ages 15, 16 and 17.

TABLE XXVIII

SEX DIFFERENCES IN IDEATIONAL LEARNING

Boys Age, Yrs.		Girls Age, Yrs.-Mos.		Difference in Months
10	=	9	7.7	4.3
11	=	10	8.2	3.8
12	=	11	7.2	4.8
13	=	12	7.7	4.3
14	=	13	8.3	3.7
15	=	15	3.3	3.3
16	=	16	10	10.0

By reference to Table XXV it will be seen that in tests A and B combined, boys excel girls at every age. This may be due in part to the fact that these tests are better suited to the interest and experience of boys than to those of girls.

CHAPTER VIII

GENERAL MENTAL DEVELOPMENT

Nature and Purpose of Experiment.—The purpose of the experiment considered here was to determine the yearly development in children by means of a series of group mental tests. The tests used are known as Pyle's *Missouri Mental Tests.* In these tests there is one form for grade school children and another form for high school. The grade school test has six parts. There are three learning tests—one visual learning test, one auditory learning test, and a substitution test. The other three tests are (1) an opposites test, (2) a rote memory test, and (3) a completion test.

The high school test is similar to the grade test except that it has an analogies test instead of the rote memory test. The tests require about fifty minutes for administration.

The Results.—The grade school test was given to the pupils of grades 4, 5, 6, 7 and 8. The results are shown in table XXIX.

The results of the high school tests are shown in table XXX.

In order to get a development curve, both the grade test and the high school test were given to fifty eighth grade pupils. It was found that the high school scores should be multiplied by 1.24 to make them equivalent to the grade test scores. All high school scores were accordingly converted into grade school scores and combined with the grade

TABLE XXIX

GRADE SCHOOL TEST

Age	Boys		Girls	
	Cases	Ave. score	Cases	Ave. score
9	40	84.3	46	99.9
10	75	117.8	69	132.1
11	80	143.5	75	152.2
12	72	148.6	91	171.3
13	58	162.6	61	166.2
14	37	161.7	25	169.6

TABLE XXX

HIGH SCHOOL TEST

Age	Boys		Girls	
	Cases	Ave. score	Cases	Ave. score
13	20	165.3	26	161.2
14	58	148.9	25	157.5
15	67	143.6	94	161.2
16	66	152.2	70	170.4
17	37	160.7	74	172.0

test scores for all ages taking both tests. The scores thus obtained are shown in table XXXI which gives both the actual and smoothed scores. The development curves

plotted from the smoothed scores of table XXXI are shown in figure 15.

TABLE XXXI

SHOWING GRADE AND HIGH SCHOOL MENTAL TESTS REDUCED TO A COMMON BASIS

Age	Boys		Girls	
	Raw score	Smoothed	Raw score	Smoothed
8	81	76	89	85
9	84	96	100	108
10	118	113	132	129
11	144	131	152	147
12	152	146	171	163
13	173	161	178	177
14	176	173	189	189
15	173	183	197	200
16	188	193	211	210
17	199	202	213	216

In table XXXII are shown the percentages which boys' scores are of the corresponding age scores of girls, computed from the actual scores.

TABLE XXXII

PERCENTAGE BOYS' SCORES ARE OF GIRLS' SCORES

Age..................	8	9	10	11	12	13	14	15	16	17
Per cent of girls' score..	91	84	89	95	89	97	93	88	89	93

The yearly percentages of improvement are shown in table XXXIII and the sex differences expressed in months are shown in table XXXIV.

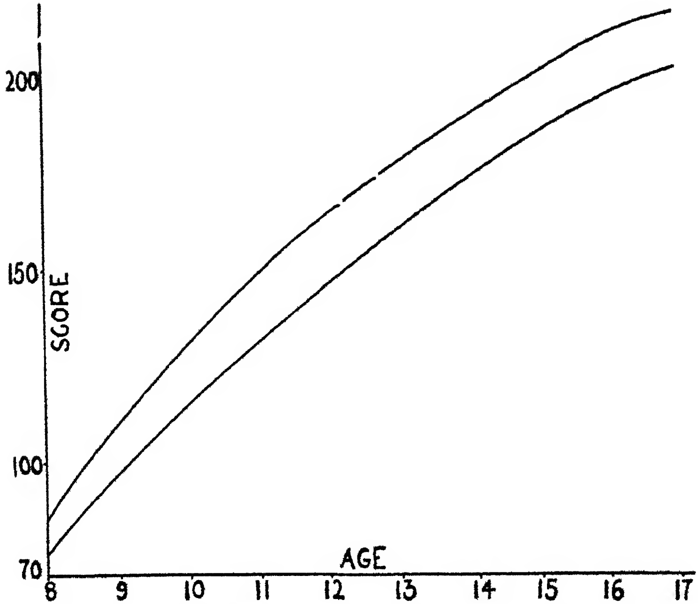

FIG. 15.—Graphs showing the yearly improvement in the mental test scores. The upper graph is for girls, the lower is for boys.

TABLE XXXIII

MENTAL TESTS—SHOWING YEARLY IMPROVEMENT EXPRESSED IN PER CENT

Age	Per cent improvement	
	Boys	Girls
8–9	26.3	27.1
9–10	17.7	19.4
10–11	15.9	14.0
11–12	11.5	10.9
12–13	10.3	8.6
13–14	7.5	6.8
14–15	5.8	5.8
15–16	5.5	5.0
16–17	4.7	2.9

TABLE XXXIV

SEX DIFFERENCES IN MONTHS—MENTAL TESTS

Boy, age	Girl, yrs.-mos.		Difference in months
9	8	5.7	6.3
10	9	2.9	9.1
11	10	1.3	10.7
12	10	11.3	12.7
13	11	10.5	13.5
14	12	8.6	15.4
15	13	6.0	18.0
16	14	4.4	19.6
17	15	2.4	21.6

Discussion and Interpretation.—When we give mental tests in school, beginning with a certain grade and ending with a certain grade, and then work up our data by ages, there will be errors in the younger and older ages. We began in the fourth grade with the mental tests. The eight year norms are too high because the duller eight year old children have not reached the fourth grade. The thirteen year and fourteen year norms are too low in the grade test because the brightest children of this age have passed on to the high school. By reducing the high school scores to a grade test basis we were able to combine all the children from age 12, where they began to overlap in the two tests. However, there is no way of correcting for ages 17 and 18 where some of the brightest have already graduated and left school. I have smoothed the scores to what is doubtless very near the correct norms.

The tables and graphs show that the yearly development as measured by the mental tests is much the same as that shown by the separate measures of various aspects of learning capacity. This is not to be wondered at for not only do the different mental functions develop with some relation to one another but four of the six tests included in grade school mental tests are virtually measures of learning capacity, for the rote memory test is essentially a learning test. Three of the six high school tests are learning tests.

CHAPTER IX

RACIAL AND OTHER DIFFERENCES IN LEARNING CAPACITY

The Learning Capacity of Negroes.—The comparison of the learning capacity of negroes and whites is based on experiments with the manthanometer, a substitution experiment, an experiment in logical memory, and one in rote memory.

In the manthanometer experiment all the negroes in the Douglas School, Columbia, Missouri from fourth grade up were tested; and all the white children in the Jefferson School, Columbia, in the corresponding grades were given the same experiment in the very same way. The comparisons thus, in the manthanometer experiment, are between the negroes of one school and the whites in another school in the same city.

The comparisons in learning capacity as determined by rote and logical memory tests are based on studies made on the negroes found in the schools of three Missouri cities, Columbia, Mexico, and Moberly, and white children in the same and other cities.

The number of negro children tested in the manthanometer experiment was 350, and the number in the memory experiment was 408. The number is, of course, too small for establishing definite racial norms, but is large enough to show the general course of development in negro children. The racial comparisons made from the smoothed scores are, I believe, legitimate.

In table XXXV are shown the comparative scores for negroes and whites in the manthanometer. The scores refer to the number of marbles correctly placed per minute.

TABLE XXXV

SCORES FOR NEGROES AND WHITES IN MANTHANOMETER EXPERIMENT

Age	White			Negroes		
	Cases	Score	Smoothed	Cases	Score	Smoothed
Girls						
10	21	14.9	15.6	9	11.4	11.5
11	20	17.2	16.4	15	12.4	12.2
12	19	16.0	17.1	9	12.7	12.7
13	28	18.2	17.9	18	13.3	13.3
14	9	18.3	18.7	18	13.8	13.9
15	3	19.6	19.5	16	14.4	14.4
Boys						
10	8	14.1	14.9	5	11.2	11.6
11	15	16.1	15.6	8	12.8	12.2
12	18	16.0	16.3	12	11.9	12.7
13	14	17.5	17.0	18	13.5	13.2
14	9	15.3	17.5	7	12.8	13.7
15	7	18.7	18.2	7	15.2	14.4

In figure 16 the distribution of negroes and whites with reference to learning capacity in the manthanometer experiment is shown. In the figure, 121 negroes of different ages are represented and an equal number of whites of corre-

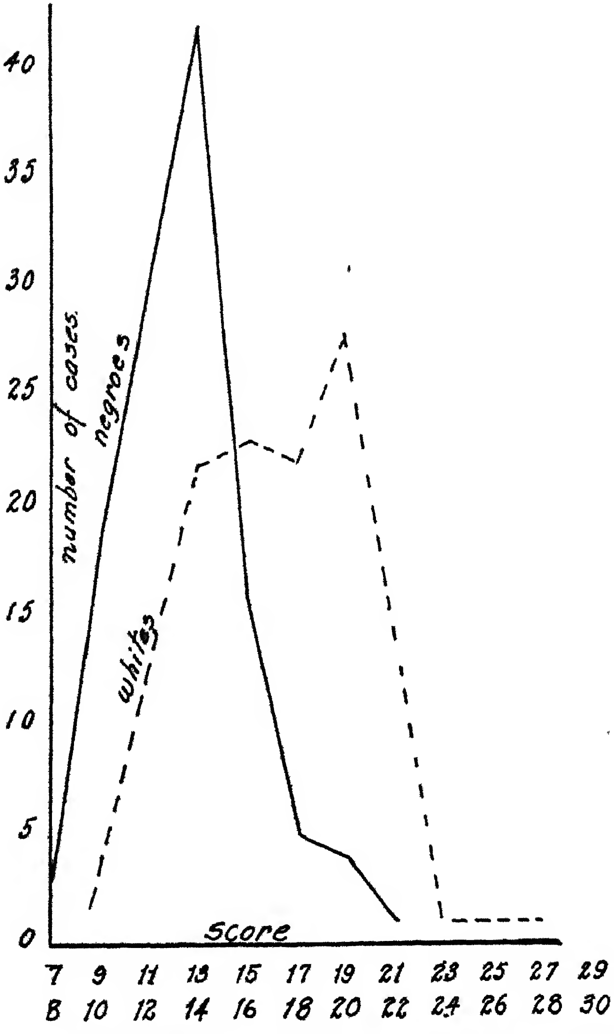

FIG. 16.—Graphs showing the distribution of negroes and whites with reference to learning capacity in the manthanometer experiment.

sponding ages. Only 8.2 per cent of the negroes equal or exceed the white median, while 90 per cent of the whites equal or exceed the negro median. Only 50 per cent of the two surfaces coincide. In these graphs the two sexes are combined.

In table XXXVI are shown the yearly improvements of negro children and white children in the manthanometer experiment. It will be noticed that the yearly percentages of improvement are much the same for negroes and for whites, being 4.6 per cent on the average for negro girls as compared with 4.5 per cent for white girls; and 4.4 per cent for negro boys as compared with 4.1 per cent for white boys.

TABLE XXXVI

YEARLY IMPROVEMENT SHOWN IN PER CENTS—MANTHANOMETER

Age	Girls		Boys	
	White per cent improvement	Negroes per cent improvement	White per cent improvement	Negroes per cent improvement
10–11	5.1	6.1	4.7	5.2
11–12	4.2	4.1	4.5	4.1
12–13	4.6	4.8	4.3	3.9
13–14	4.5	4.5	3.0	3.8
14–15	4.3	3.6	4.0	5.1
Average....	4.5	4.6	4.1	4.4

In table XXXVII are shown the percentages which the negro scores are of the corresponding scores of white children.

TABLE XXXVII

PER CENT WHICH NEGRO SCORES ARE OF WHITE

Girls

Age	10	11	12	13	14	15
Per cent	74	74	74	74	74	73

Boys

Age	10	11	12	13	14	15
Per cent	78	78	78	78	78	79

In table XXXVIII are found the smoothed records for negroes and whites in Substitution, Rote Memory, and

TABLE XXXVIII

SUBSTITUTION

Age	8	9	10	11	12	13	14	15	16	Ave.
Negro boys	4.8	6	7.4	9	11	14.5	18.5	23.3	28.1	13.6
White boys	16.8	20	22.6	26	29	32	35	37.8	39.4	28.7
Negro girls	4.7	6.8	8.8	11.4	14	17.2	20.6	24.2	27.8	15.1
White girls	19.2	23.2	27.0	30.6	34.4	37.4	40.2	42.2	43.2	33.0

ROTE MEMORY

Age	8	9	10	11	12	13	14	15	16	Ave.
Negro boys	13	15	17.2	19.7	22.2	26.2	30.7	36.2	41.4	24.6
White boys	27.5	29.4	31.4	33.4	35.2	37.0	38.4	39.8	41.4	34.8
Negro girls	17.0	18.0	20.8	23.6	27.2	31.5	35.0	38.6	43.2	28.3
White girls	27.5	29.8	32.1	34.4	36.5	38.8	40.5	42.0	43.2	36.1

TABLE XXXVIII.—*Continued*

LOGICAL MEMORY

Age	8	9	10	11	12	13	14	15	16	Ave.
Negro boys......	11.5	14.4	16.7	18.7	20.5	22.0	23.4	24.4	25.4	19.7
White boys......	13.5	21.0	23.4	24.5	25.6	26.6	27.6	28.4	29.0	24.4
Negro girls.......	12.5	14.5	16.8	18.8	20.6	22.2	23.8	25.2	26.4	20.1
White girls.......	18.0	19.8	21.8	23.7	25.7	27.5	29.1	30.6	32.0	25.3

Logical Memory, and in table XXXIX are shown the percentages which the negro scores are of the corresponding scores of whites, for the manthanometer experiment and for substitution, rote memory and logical memory.

TABLE XXXIX

SHOWING THE PERCENTAGES WHICH NEGRO SCORES ARE OF THE CORRESPONDING SCORES OF WHITES

Age	8	9	10	11	12	13	14	15	16	Ave.
					Boys					
Manthanometer..	..	..	78	78	78	78	78	79	..	78
Substitution......	29	30	33	35	38	45	53	62	72	44
Rote memory....	47	51	55	59	63	71	80	91	100	68.5
Logical memory	85	69	71	76	80	83	85	86	88	80.3
Average.........	..	..	59	52	65	69	74	80		

TABLE XXXIX.—*Continued*

Girls

Manthanometer. .	..	..	74	74	74	74	74	73	..	73.8
Substitution......	25	30	33	37	41	46	51	57	64	42.6
Rote memory....	62	60	65	69	75	81	86	92	100	76.6
Logical memory .	69	73	77	79	80	71	82	82	83	78.4
Average........	..	..	63	65	68	71	73	76		

Learning Capacity of Indian Children.—Under my direction Mrs. Valeria Pearl Lappin gave seven mental tests

TABLE XL

PERCENTAGE INDIAN SCORES ARE OF CORRESPONDING SCORES OF URBAN WHITE CHILDREN

Age		10	11	12	13	14	15	16	17	18	Ave.
Substitution	Boys	54.2	55.3	65.8	66.1	64.7	69.5	60.0	52.3	60.4	60.9
	Girls	69.3	50.9	54.8	52.8	65.6	59.7	56.0	46.5	58.9	57.1
Logical memory	Boys	78.4	74.8	76.3	91.2	....	....	....	....	....	80.1
	Girls	60.7	70.0	64.8	58.5	....	....	....	....	....	63.5
Rote memory concrete.	Boys	75.1	69.0	72.2	76.1	74.3	72.2	78.6	70.9	67.4	72.8
	Girls	72.2	68.7	70.6	66.7	71.6	74.8	66.6	68.3	72.6	70.2
Rote memory abstract.	Boys	70.3	67.5	66.7	70.9	69.1	69.0	79.3	64.7	56.8	60.8
	Girls	73.3	62.1	64.9	65.0	63.2	73.4	60.2	71.8	60.0	65.9
Analogues............	Boys	45.0	51.0	43.0	40.3	34.6	24.9	25.6	34.6	13.0	34.6
	Girls	62.8	49.1	28.8	32.0	23.5	28.3	20.7	18.6	6.8	30.6
Word building.........	Boys	55.3	47.5	57.9	45.5	40.1	39.6	39.8	41.4	33.4	44.5
	Girls	49.1	49.9	51.0	44.2	49.1	44.0	40.9	23.3	28.7	42.2
Free association.......	Boys	29.2	27.9	27.7	31.4	32.0	22.7	30.3	24.8	33.9	28.8
	Girls	40.5	29.0	33.0	28.1	26.2	44.5	27.8	28.8	16.3	30.5
Average..............	Boys	58	56	59	60	52	50	52	48	44	53
	Girls	61	54	53	50	50	54	45	43	41	50

to five hundred Indian boys and girls in eight government Indian schools in Oklahoma. Nineteen different tribes were represented. The results of the tests are given in table XL which shows the percentage which the Indian scores are of corresponding scores of white children.

In all the tests combined the Indian boys make a score which is 53 per cent of the scores of white children. The Indian girls make a score 50 per cent of that of white girls.

In the substitution test the average Indian score is for boys 61 per cent of the white boy norm, and for girls 57 per cent of the white girl norm. The Indians were under a disadvantage because they did not have complete mastery of English. In the substitution experiment this disadvantage did not exist. The results from the substitution experiment may therefore be taken as fairly representing their learning capacity.

Learning Capacity of Chinese Children.—Under my direction Dr. J. W. Creighton gave a series of group mental tests to 305 boys and 119 girls in the "new style" schools of Canton, China. The results were compared with the results obtained from children of corresponding ages in the schools of Fulton, Missouri. Dr. Creighton gave the experiments to the American children, and the procedure was precisely the same.

Of course there were language difficulties, and the question of selection also arises. How nearly representative were the Chinese children? I can not say. It was Dr. Creighton's opinion that the Chinese children were fairly representative.

Considering only the substitution experiment as being most free from language difficulties and also the best measure of learning capacity, I find that Chinese boys ages 12 to 17 make a score which is 88 per cent of the corresponding

score of American white boys, and Chinese girls make a score which is 77 per cent of that of American white girls.

However, if we consider all the experiments given the Chinese, the results are very similar. We may say that the learning capacity and the general intelligence of the Chinese students is in the case of boys about 90 per cent of that of white boys; and the Chinese girls have a learning capacity and a general intelligence about 80 per cent of that of white girls.

In table XLI Chinese, Negroes and Indians are compared on the basis of the substitution experiment. The numbers represent the percentages which their several learning capacities are of white children of corresponding age and sex. The ages compared are 10 to 16 for Indians and Negroes and 12 to 17 for Chinese.

TABLE XLI

SHOWING THE PERCENTAGES WHICH THE SUBSTITUTION SCORES OF NEGROES, INDIANS AND CHINESE CHILDREN ARE OF THE CORRESPONDING SCORES OF AMERICAN CHILDREN

	Boys	Girls
Negroes	44	43
Indians	62	58
Chinese	88	77

THE LEARNING CAPACITY OF RURAL CHILDREN

The learning capacity of children in one rural community may differ much from the learning capacity of children in another rural community. However, a comparison of the rural children in one Missouri county with the children of Missouri cities may be of some value. Of course, how the children of this county (MacDonald) compare with the rural children in other Missouri counties or of the counties of other states, I do not know.

Under my direction Dr. P. E. Collings made studies of the mental and physical development of all the rural school children in McDonald County of which he was at the time county superintendent. From his studies I shall give only the results of the substitution experiment, which are shown in table XLII which gives the percentages of the rural scores as compared with urban scores for ages 8 to 14. There were about 120 rural children of each age of each sex.

TABLE XLII

SHOWING THE PERCENTAGES WHICH THE SCORES OF RURAL CHILDREN ARE OF THE CORRESPONDING SCORES OF CITY CHILDREN OF THE SAME AGE AND SEX

Age	8	9	10	11	12	13	14	Ave.
Boys.....	60	65	68	81	82	98	95	78
Girls.....	56	61	76	80	97	97	100	81

One interesting fact which the table shows is that at age 8 the rural children are but little over half as efficient as are city children and that as they grow older they approach nearer and nearer to the efficiency of city children. It may be added that all the other experiments made by Collings were in general agreement with the result I have given for the substitution experiment.

It seems to me that the legitimate explanation for the facts is as follows: (1) The country children show up more poorly partly because they really have poorer learning capacity than do city children and partly because of poorer training. The young rural children get very little attention in school. When given an experiment, they do not so readily understand what is expected of them, and do not

know so well how to take hold of tasks given them, because they have not had much practice that would prepare them for such things.

(2) In the later years, the rural children come nearer to the city children partly because they have gained somewhat, relatively, by training, and partly because in rural communities more dull children drop out of school than is the case in the city. These various factors would explain the differences found. Whether the assumptions made above are correct, of course, I do not know. They are certainly possible and it seems to me, quite probable.

CHAPTER X

COMPARATIVE STUDY AND INTERPRETATION

In table XLIII the results of all the experiments are brought together. The numbers represent the percentages which the boys' scores are of the corresponding girls' scores. At the bottom of the table, the upper row of averages is obtained by combining all the experiments. The second

TABLE XLIII

PER CENT WHICH BOYS ARE OF GIRLS AT DIFFERENT AGES

Age	6	7	8	9	10	11	12	13	14	15	16	17	18
Card sorting	..	..	88	88	84	86	90	93	90	92	98	98	91
Marble sorting	78	94	98	91	99	88	92	88					
Manthanometer	..	..	81	85	89	92	94	96	98	103	102	104	
Substitution	..	..	85	90	85	84	84	83	85	90	87	92	86
Mirror drawing	..	..	..	129	133	114	99	97	97	88	78	72	
Ideational learning	..	..	..	81	87	93	92	95	96	104	107	111	
Mental tests	..	..	91	84	89	95	89	97	93	88	89	93	
Average of all	..	..	89	93	95	93	91	93	93	93	93	95	
Average of four motor	..	..	88	89	89	88	90	90	91	95	96	98	
Average of ideas and mental	..	..	..	83	88	94	91	96	95	96	98	102	

row of averages combines the four motor experiments: card-sorting, marble-sorting, manthanometer, and substitution. The lower row of averages combines the ideational learning tests and the mental tests.

In figure 17 the results are shown graphically. The horizontal line represents girls. Graph A below represents

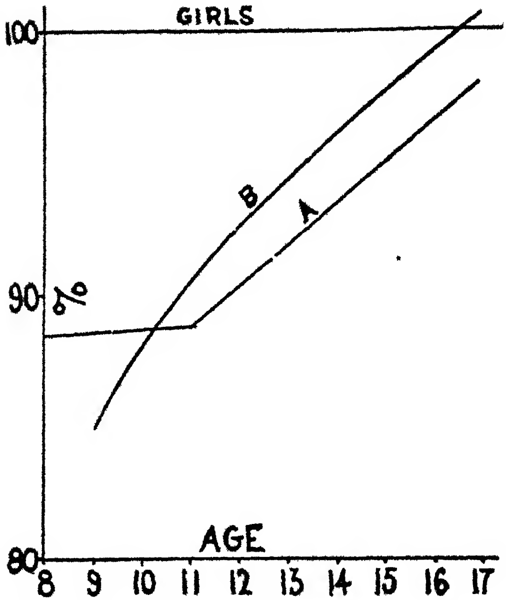

FIG. 17.—The upper horizontal represents the learning capacity of girls. Graphs A and B show the percentages which the learning capacity of boys at the various ages is of the corresponding learning capacity of girls. A represents motor learning, and B represents ideational learning.

the percentage which the boys' scores for the motor tests are of the girls' scores at the various ages. Graph B similarly shows the relation of boys to girls in ideational learning and the mental tests combined.

It is seen that after age ten, boys do not come so close to girls in motor learning as they do in ideational forms of learning. Boys show up better in forms of learning involving so-called thinking.

The mirror experiment seems to give results contrary to the other experiments. Up to age eleven the boys excel. From age twelve the girls excel. From age twelve the boys lose steadily as compared with the girls. At ages 9 to 10 the boys are very superior to the girls, while at ages 16 to 17 they are very inferior. I am not able to explain the course of development in this type of learning. Whether the influence is to be found in trial and error learning itself, or in the factor of inhibition, or in the possible greater use of mirrors by girls in the later years, I can not say. The matter is left for future experiments.

In the ideational learning, it seems that the boys reach the ability of girls at age fifteen. I feel sure that the standing of the boys is higher than it ought to be, because, as already stated, the test was better adapted to them. In the mental tests, the boys at no time were quite equal to the girls. It is perhaps safe to say that in so-called mental learning, boys reach the capacity of girls at least by the end of adolescence.

In table XLIV and figure 18 are shown the percentages of growth for boys and girls for the different ages in all experiments. These percentages show the growths for each year as compared with the score made the preceding year. From 8 to 12, the average improvement for girls is

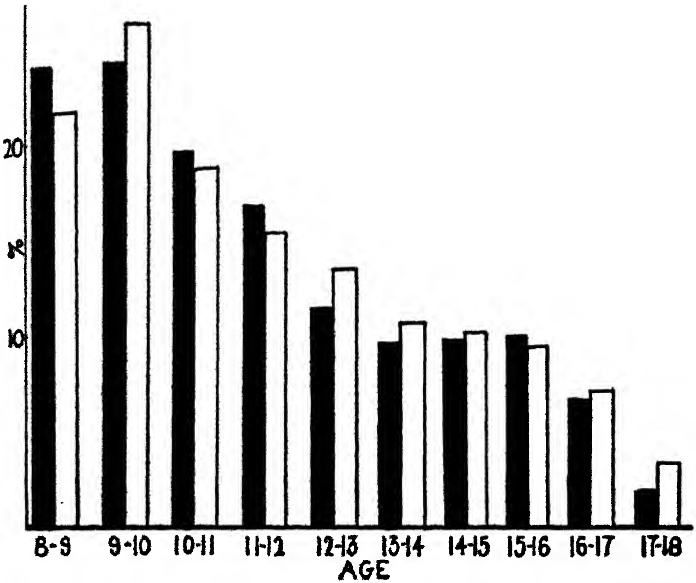

FIG. 18.—Percentage of growth in learning capacity, all experiments combined. The black columns are for girls and the light columns are for boys.

24 per cent; for boys 23.7. From age 13 to 18 the average improvement of boys is 10.5, for girls only 9.5.

TABLE XLIV

YEARLY IMPROVEMENT IN PER CENT

Exps.	Sex	6 to 7	7 to 8	8 to 9	9 to 10	10 to 11	11 to 12	12 to 13	13 to 14	14 to 15	15 to 16	16 to 17	17 to 18
Cards	B	....	....	20.3	14.8	9.4	9.1	9.2	6.8	4.6	4 9	3.2	2.0
	G	....	....	23.4	17.5	8.9	6.9	5.3	5.1	3.7	1.8	2.3	0.9
Marbles	B	38.5	21.9	13.7	9.7	8.7	8.3						
	G	18.3	16.0	13.8	11.7	10.5	9.0						
Manthanometer	B	....	....	....	14.3	11.7	9.4	7.6	6.4	6.1	6.7	4.8	4 1
	G	....	....	....	8.2	6.5	6.8	5.2	4.6	4.4	3.4	3.1	2.0
Substitution	B	....	....	26.7	21.1	17.4	14.8	12.9	11.4	10.3	9.3	8.5	7.5
	G	....	....	31.8	21.8	17.6	14.2	11.7	9.7	8.9	8.9	4.1	2.4
Mirror	B	....	....	....	38.0	28.0	23.0	19.0	17.0	15.0	16.0	8.6	
	G	....	....	....	33.0	50.0	40.0	21.0	18.0	26.0	30.0	18.0	
Ideas	B	....	....	....	68.0	38.0	30.0	21.0	16.0	19.0	15.0	13.0	
	G	....	....	....	57.0	29.0	31.0	17.0	14.0	10.0	11.0	9.0	
Mental	B	....	....	26.3	17.7	15.9	11.5	10.3	7.5	5.8	5.5	4.7	
	G	....	....	27.1	19.4	14.0	11.9	8.6	6.8	5.8	5.0	2.9	
Average	B	....	....	21.8	26.2	18.4	15.2	13.3	10.9	10.1	9.6	7.1	4.5
	G	....	....	24.0	24.1	19.5	16.9	11.5	9.7	9.8	10.0	6.6	1.8

It seems clear that at least in most forms of learning, girls improve most in the earlier years, say up to eleven or twelve, and boys show their improvement relatively later. Of course, the percentage improvement is much greater for both sexes in the earlier years, being more than twice as great before adolescence as during adolescence.

In ideational learning the percentage of yearly growth is greater for boys than for girls at every age in the years

studied except ages eleven to twelve. In the mental tests the boys improve more from age ten on than the girls do.

The evidence seems to indicate that girls mature in learning capacity much more rapidly than boys up to the age of puberty, or at least nearly to puberty. After this time the boys mature relatively faster. However, this early rapid growth of girls puts them far ahead of the boys. Even after the yearly growth of boys becomes accelerated as compared to the growth of girls, it takes the boys several years to catch up with the girls and they probably do not catch up until about the end of the high school age.

Mental development seems, roughly at least, to parallel physical development. Girls pass to physical maturity at a much more rapid rate than do boys. Although physically girls are smaller at birth and are to be much smaller at maturity than males, there is a period in adolescence when they surpass boys in height and weight.

The development of muscular speed in girls as measured by the tapping experiment shows a similar course, although girls are at no time faster than boys.

The faster maturing of girls in learning capacity is merely a matter of the more rapid development of the nervous system, and doubtless involves all forms of learning. It is difficult, in comparing girls and boys, to determine what differences are due to growth and what to inherent sex differences. It is also difficult to apportion properly the effects of difference in training and experience. It seems that the superiority of girls is greater in mechanical, motor forms of learning than in the forms of learning involving reasoning, but this difference may be merely the outcome of the difference in the kinds of lives boys and girls live. Certain sex differences are fairly evident. The explanation of the differences are not evident.

Sex Differences in Accuracy.—In table XV are shown the sex differences in accuracy in the marble-sorting experiment. Although the boys worked more slowly than the girls, they made 7.05 mistakes where the girls made 6.23. The mistakes made by the boys were 14.7 per cent of their score, while the mistakes made by the girls were only 12.0 per cent of their score.

The girls were, therefore, not only faster at marble sorting than the boys but more accurate than the boys.

In the manthanometer experiment, the results are somewhat different. In the first test the girls make, for all the different ages, almost 10 per cent more mistakes. In the second test boys and girls make the same number of mistakes. This means, of course, that the boys master the experiment more readily than the girls. In the later years of adolescence, boys actually excel the girls in this type of learning. It looks as if boys are better than girls at mastering this type of experiment, if we make allowance for the greater maturity of the girls as compared with the boys.

Sex Variability.—In table VII is shown the variability of boys and girls in the card-sorting experiment. The table shows about the same absolute amount of variation for boys and girls but the percentage is slightly greater for boys.

In table XLV is shown the variability for boys and girls in the marble-sorting experiment. The absolute variability of the girls is slightly greater than that of boys, but the coefficient is slightly greater for boys, being 30.2 per cent for girls and 31.8 per cent for boys. The average number of mistakes made by the girls of all ages was 15.5, for boys 15.1. Since the boys made lower efficiency scores, their coefficient of variability was higher than that of girls, by 1.6 per cent.

It is interesting to compare boys and girls with reference to the relative number of brightest and dullest in the

TABLE XLV

VARIABILITY—MARBLE SORTING

Age	Actual standard deviation		Coefficient of variability	
	Girls	Boys	Girls	Boys
6	12.6	9.9	39.7	40.0
7	13.4	13.1	34.3	35.8
8	14.2	13.8	33.2	33.1
9	16.6	15.8	33.7	35.1
10	16.2	16.4	30.2	30.9
11	17.7	15.4	28.2	27.8
12	16.1	17.2	24.0	28.1
13	16.1	16.4	24.2	27.8
14	16.9	17.6	24.9	28.3
Average....	15.5	15.1	30.2	31.8

marble-sorting experiment. If we take the number of boys for each year making the highest scores and compare with the number of girls making these scores or higher, we find seventeen boys making the high scores and sixty-one girls. On the other hand eleven boys of the different ages make the lowest scores and only four girls make scores so low.

We may say, therefore, that in the marble-sorting experiment girls not only make higher average scores at the different ages but there are more exceptionally bright girls and fewer exceptionally dull girls than boys. This means merely that the whole frequency surface representing girls is farther up the scale than is that of boys.

Range of Ability.—In figure 19 is shown the distribution of all the boys of each age, in the marble-sorting experiment.

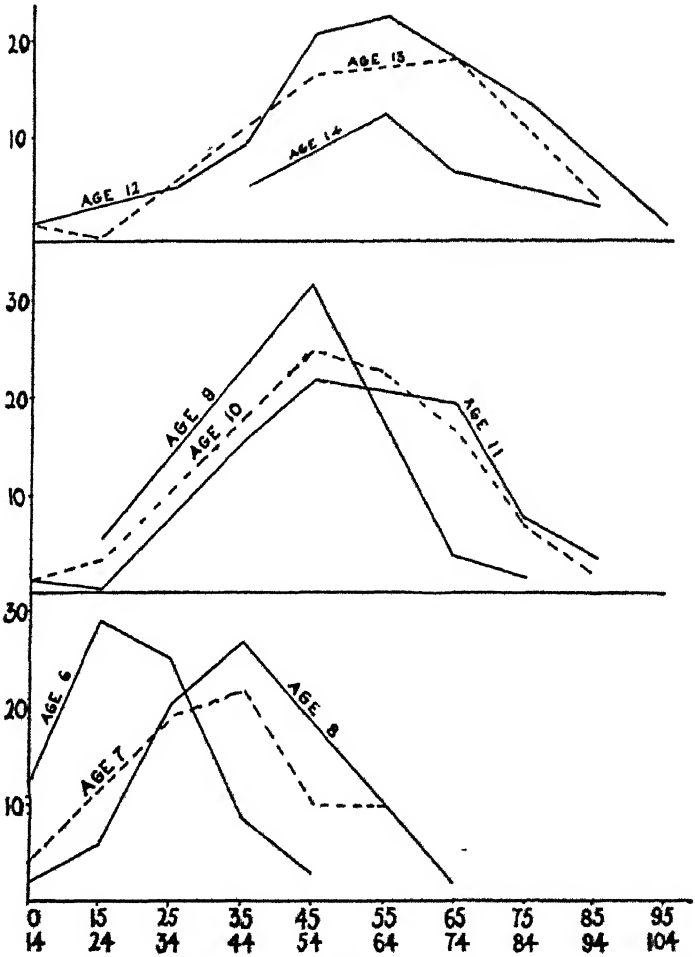

FIG. 19.—Marble-sorting distribution curves for boys of the different ages from 6 to 14.

It will be seen that the frequency surface moves to the right with increasing age, but much more slowly in the upper ages. There is great overlapping in ability of boys of adjacent ages. While the median and higher ability move to the right, the older ages continue to be represented among the lowest scores also.

In figure 20 girls of ages 7 and 12 are compared. It will be seen that at these ages five years apart there is still overlapping. Some girls seven years old do this experiment as well as some girls twelve years old.

In figure 21 the usual distributions of the sexes are shown. The figure represents the distribution of 103 boys and 104 girls twelve years old with reference to their ability at marble sorting. It is seen that the girls' median is higher and their best score is higher than the best score made by boys. There are fewer girls making low scores, and no girl at all making the lowest score made by boys.

The great range of abilities in children of the same age, the great overlapping of abilities in children of different ages, and the great sex differences in ability present difficult problems to the teacher and the administrator. It seems to the writer that teaching can be made much more effective if children are grouped according to their learning capacity, those of approximately the same ability being placed in the same classes. Since learning capacity for different types of learning may be different in the same pupil, and since the different types of learning capacity do not develop at the same rate, it is probable that different groupings may be necessary for different classes, in the case of the same pupils. However, these suggestions may be outside the province of psychology. It is the business of psychology to discover the facts of mental development. The use to be made of these facts by the school administrator is another matter.

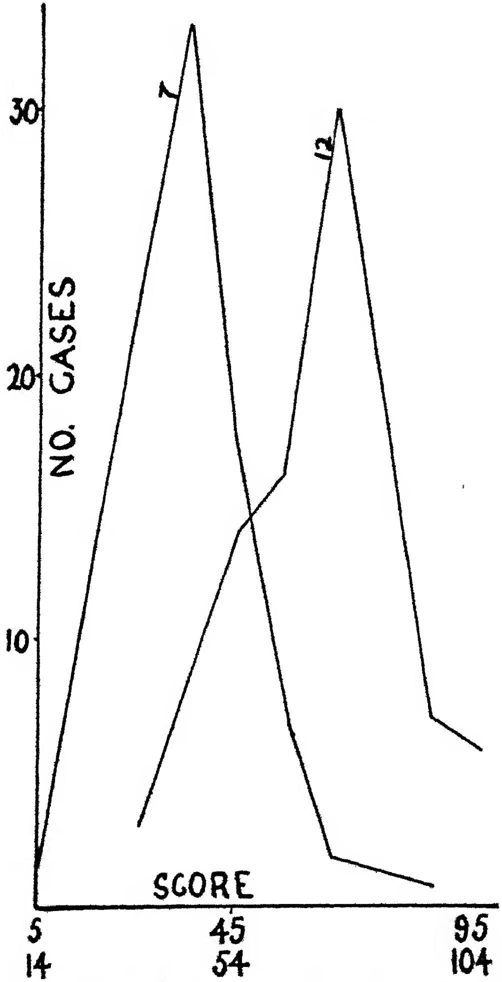

FIG. 20.—Distribution curves for girls age 7 and girls age 12. Marble sorting.

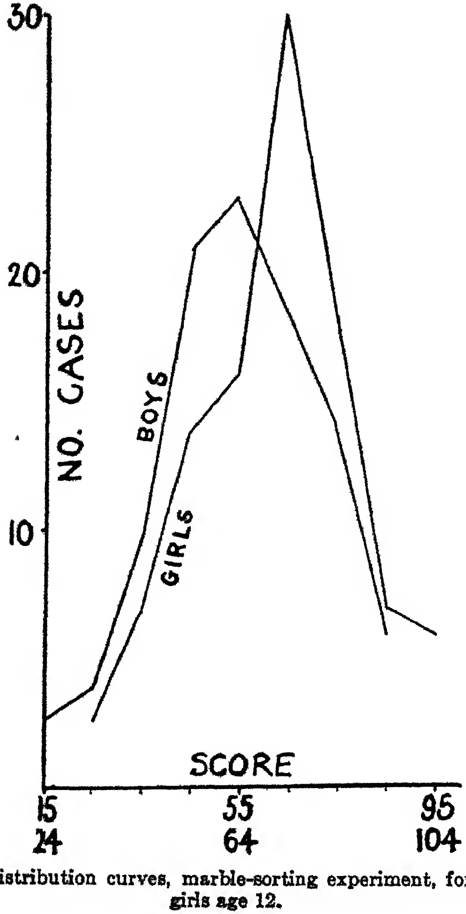

Fig. 21.—Distribution curves, marble-sorting experiment, for boys and girls age 12.

CHAPTER XI

A THEORY OF LEARNING[1]

The purpose of this chapter is to set forth a theory of brain action that will explain the various facts of the psychology of learning. It is necessary first to see just what the psychological facts are.

Learning is a process of connecting. In habit-formation we are establishing connections between responses and their stimuli. In knowledge-getting we are establishing connections between ideas.

The first thing to be noticed about these connections is that they are either between the parts of simultaneous experience, or between one experience and another which immediately follows it. It is possible that connections are also established between experiences that are not temporally adjacent but are separated by a short interval of time. The following may serve as an illustration of a connection established between the parts of a simultaneous experience: I see a man and hear his name spoken at the same time. As a result there is a connection established in my mind between the image of the man and his name. The image of the man and the representation of his name may take various forms. Connections between successive experiences may be illustrated by piano playing. The stimulus is the perception of notes in certain positions on the musical scale. The response is the striking of certain keys on the piano. Learn-

[1] This chapter first appeared in the Psychological Review for July, 1924, and is reprinted here by permission.

ing to play the piano is the process of establishing, fixing, the connections between the visual perception and the motor response. After practice, the idea of the note and its position may take the place of perception of the note.

The second psychological fact has reference to the strength of connections. Not only do the parts of experiences, simultaneous or successive, become connected, but there is a difference in the strength of connections. Some connections are much stronger than others. Connections formed between processes of attentive consciousness are stronger than connections between processes of inattentive consciousness.

Consciousness ordinarily has a high attentive level and a low attentive level, *i.e.* a group of clear processes and a group of vague processes. In some cases there may be more than two levels of clearness. The connections established between the processes of clear consciousness are relatively strong; while those established between the processes of vague consciousness are relatively weak. Two cases may be noticed: (1) A bond that is formed between clear processes of consciousness is stronger than a bond that is formed at the same time between processes that are vague. In fact, connections formed between the vague processes usually immediately disappear. It may be even nearer the truth to say that such connections are not formed. (2) Connections formed between simultaneous or successive processes that are clear may vary in strength in accordance with the degree of clearness. The clearer the processes, the higher the level of attention, the stronger are the connections that are formed.

A third fact concerns the difference between good and poor learners. People who are good learners have what is commonly called a *high power of concentration.* In more

scientific phraseology, their conscious processes have a focus clear and well-defined as compared to the simultaneous vague processes. Poor learners are poor in attention. Their conscious processes are not clear-cut; the difference between the clear and the vague is not so marked. Good learners are able to stick to a task and maintain a continuously high level of attention. They have a continued succession of clear processes grouped about a central thought or idea. Poor learners vacillate; they can not stick to a task long at a time. The consciousness of the poor learners differ from that of the good learner both transversely and longitudinally. On the one hand, it does not have the marked difference in clearness-value between what may be called the high level and the low level of consciousness. On the other hand there is not the continued succession of clear processes related to the same idea as is the case with the good learner. In plain words, the poor learner does not work so long at the same task as does the good learner nor does he work so effectively while he does work.

Another difference between good and poor learners is that the former see what is significant. The important, meaningful aspects of their experience is apparent to them. The world in general is to them a more meaningful world, and each individual experience is to them richer in meaning than is the case with the poor learner. Aspects and attributes of objects appear to the good learner that do not appear to the poor learner. To illustrate: in sorting cards into separate boxes, good learners discover devices of associating or fixing the location of different numbers that never appear to poor learners. So, also, in learning a series of nonsense syllables, the good learner makes a meaningful series out of what remains meaningless to the poor learner. In studying a book in the ordinary process of preparing lessons, the good

learners look for meanings and find them, while poor learners get little or nothing from the study.

It has been often said that genius is the ability to see similarity in different experiences. Now, similarity of experience is in reality *identity* of experience. To the good learner subtle identities in different experiences appear that are entirely unnoticed by the poor learner. Newton identified the rate of acceleration of the falling moon and the rate of acceleration of the falling apple as due to the same cause.

Such, in brief, are the main psychological facts as they appear to observation and experiment. We must look to the brain for an explanation of the facts—to brain anatomy and physiology. The anatomy of the brain is fairly well known, but the brain physiologist can not yet answer all the questions which the student of the learning process would like to have answered. We must resort to theory. We must picture a form of brain action that will harmonize with the observed facts. We do this in the hope that our picture, our theory, may guide or at least stimulate investigation.

Most of the psychological facts concerning the learning process center in one way or another about attention. An acceptable physiological theory of learning must therefore be in harmony with the facts of attention. The physiological correlate of attention is cerebral focalization. The brain is a unifier. The sensory stimulations constantly excite it to activity, but there is always a synthesis of this activity. A process of unification is always going on. Unification is accomplished in this way: a few processes become focal, monopolizing the brain activity for the time, while the other simultaneous processes are wholly or partially inhibited. That is to say, they proceed on a lower level of activity or are suppressed altogether. One of

the chief functions of the brain seems to be to harmonize response and stimulus, *i.e.* to unify action. We can not respond at the same time to all the stimulations of the moment. Natural selection has developed in man a brain in which there is always a selective synthesis of activity, a few processes becoming focal, and monopolizing for the moment the function of initiating action. All other simultaneous cerebral activities are wholly or partially inhibited. Three laws of brain action can be formulated that will account for all the facts in the case of bonds of simultaneous experience. (1) Simultaneous brain activities are connected. (2) Only in focalized brain activities are strong connections formed. (3) The more intense and vigorous the focalized brain action, the stronger are the associative bonds that are formed.

The brain is a theater of constantly contending influences. In it a resultant is constantly established. It is as if there were an influence always working toward focalization. This influence is positive. Another influence always works toward suppression or inhibition. This influence may be considered negative. Although our brain is a composite, although there are visual centers, auditory centers, smell centers, etc., the brain seems always to work more or less as a whole. It does this by facilitating, focalizing, a few activities, and inhibiting all other simultaneous activities. It is as if the brain had only a certain, definite amount of energy, and at any one moment uses this energy in a restricted direction or field.

The excitations that constitute brain activity may be thought of as if they resembled electric currents. Now, an electric current of a given pressure or potential will be relatively weak, if it pass through many conductors. That is to say, if a current is divided and passes through several con-

ductors, it will be relatively weak in all of them. The same thing seems to be true of neural currents. A neural current may be thought of as having a certain potential or pressure. If it is diffused by passing through several routes it will be everywhere weak. If its passage is restricted to one nerve path or to a very few, it will be relatively strong. Some people seem to have high-pressure brains; others, low-pressure brains. In high-pressure brains, the difference between the focalized and non-focalized activities is great. In low-pressure brains, there is not much difference between the focalized and non-focalized activities. The high-pressure brain forms strong and persistent associations between different activities. People having high-pressure brains are good learners; those having low-pressure brains are poor learners. To the person having a low-pressure brain, experiences are much alike. There is not to him the clear-cut difference in the importance of things which the person of high-pressure brain always sees.

To return now to the three laws of brain action; strong bonds are formed between simultaneous brain activities. This is not theory but a statement of fact, though our explanation of the reason why such bonds should be formed must be theoretical. Let us take the case of two simultaneous focal brain activities, and let us suppose that one of these activities is in neurone *X*, and the other in neurone *Y*. Excitation in *X* passes out along the axone of the neurone to all parts of the brain, most where there is the least resistance and least where there is most resistance. The same thing is true concerning the excitation in *Y*. Now we have to make only one postulate to be able to explain why *X* becomes coupled with *Y*.

The postulate is the following. The dendrites of a cell in action make good connections with the brush ends

that touch them. The more violent the neural activity, the better is the connection. It therefore follows that the excitation going out from X finds Y most open. The excitation going out from Y finds X most open. X flows into Y and Y flows into X. A pattern of brain action is formed, the after-effect of which is memory. Afterward, if X is aroused, the excitation passes over to Y because of the previous connection. And if Y is aroused, it passes over to X for the same reason. Usually both X and Y will have other connections established. The direction which an excitation will take from either at any given time will depend upon the relative strengths of the various connections.

Our hypothesis accounts only for connections established between simultaneous activities, but connections are also established between successive activities. How can we account for the latter type of connection? Neural activity does not cease suddenly. Suppose X is followed immediately by Y, and that Y is peripherally excited before the X activity has ceased; the X activity will pass into Y because Y will be most open. Y will not always go to X, but will take the path of least resistance. If another excitation, Z is immediately peripherally aroused, Y will find Z most open and will discharge into Z. In a series of brain activities, each immediately and peripherally aroused, the strongest associative connections will be in the forward direction. The connections will not only be between adjacent temporal elements but between elements which are temporally distant from each other. X not only discharges into Y but to some extent into Z, provided Z-excitation starts before X has ceased. Direct connections are established between activity X and all other brain activities that come after, before X has ceased.

One of the characteristics of the good learner mentioned above is the ability to see significance. To the good learner significant meanings come quickly; or, at any rate, they *come*. To the slow learner they come slowly or not at all. The explanation, in terms of brain physiology is as follows: The meaning of any particular experience depends upon the organization of past experience. The organization of experience depends upon the associative paths established in the brain. The strength and persistence of these paths, as explained above, depended originally upon focalized brain activity. Therefore, at any particular moment, the meaningfulness of an experience depends upon the degree of focalized brain activity at that time. The ability of an excitation to arouse activity in associative brain paths depends upon the pressure of the excitation. How pervious the associative paths are depends upon the strength of previous brain activities, for it was through such activities that the bonds or paths were organized. It is, of course, possible that there are individual differences in the number of association fibers, the good learners having more of such fibers, which would give them a better associative apparatus.

The essential part of our hypothesis is, therefore, to be found in the focalized activity of the brain. The associative bonds, the forming of which constitutes learning, are established in focalized brain activities. There go on in the brain constantly facilitating and inhibiting processes. The best learners are those whose brains function best with reference to facilitation and inhibition. The brain of the good learner is selective. It is most serviceable and economical in the use of neural energy. In it there is always a sharp and well-marked separation of the focalized activities, and suppression of all other activities. On the other hand, the brain of the poor learner is not a serviceable brain. Its energies are

wasted among many processes. It does not seem able to accomplish the segregation and facilitation of a few activities and the suppression of all others. The focalizing, facilitating, and inhibiting functions of the brain doubtless underlie general intelligence and general learning capacity. These characteristics of the brain which our hypothesis demands are probably innate and not much affected by experience.

INDEX